Surface geology of Hungary

Explanatory notes to the
Geological map of Hungary
(1:500 000)

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Introduction

Geological mapping is the oldest research method for establishing a base for geological knowledge (Lyell 1830). The visible and concrete result of this method is a geological map of our wider and narrower environment, complete with an explanatory book; the purpose of the latter is to help with the interpretation. The development of new geological research methods, and the information gathered from these, help towards discovering more aboutthe geological build-up of a particular country — in this case Hungary. Furthermore, it necessitates the compilation of new detailed geological maps which provide an overview of Hungary in accordance with the most up-to-date knowledge and technology available, along with explanatory books helping their interpretation (Kercsmár et al. 2015).

The first "classical" geological map depicting the whole Carpathian Basin (and thus, the whole territory of Hungary) was published in Vienna, at the time of the Austro-Hungarian Empire (Hauer 1867). It was followed thirty years later (in 1896) by the 1:1,000,000-scale Geological Map of Hungary, which was published by the Hungarian Geological Society and the Hungarian Royal Geological Institute, under the patronage of Andor Semsey (Böckh et al. 1896). After another thirty years, in 1922, a new geological map was published of Hungary at a scale of 1:900,000 (Lóczy, Papp 1922). Later a 1:300,000-scale map was compiled, representing the new area of the country, which lost two-thirds of its territory after WW1 (Balogh et al. 1956). The latest published geological overview map (1:500,000) of Hungary dates back 30 years (Fülöp et al. 1984). However, no explanatory book was made to accompany this map. Since that time our knowledge about the geology of the country has been expanded with (i) the geological mapping of several regions (Korpás ed. 1998; Budai et al. 1999, Gyalog, Horváth eds 2004, Szentpétery, Less eds 2006, Pelikán, Budai eds 2005, Budai, Fodor eds 2009) (ii) with stratigraphic and litostratigraphic summaries (Gyalog ed. 1996, Bérczi, Jámbor eds 1999, Gyalog, Budai eds 2004), and (iii) with comprehensive monographic works (Fülöp 1990, 1994; Haas 2004).

At the beginning of the 1990s a lithostratigraphy-based uniform legend system of the geological formations of Hungary was established. This was in line with the objectives laid down in the frame of the EOFT project (Egységes Földtani Térképrendszerek = "Unified National Geological Map System") of the Geological Institute of Hungary (Gyalog ed. 1996). Based on this uniform classification, ten years later a 1:100,000-scale digital geological map, was compiled (Gyalog ed. 2005). On the basis of the 1:100,000-scale map series (containing 88 map sheets), four years later a Geological Atlas of Hungary was published (Budai, Gyalog eds 2009). It contained a 1:200,000-scale geological map, compiled on the basis of the map (Gyalog, Budai eds 2009).

From these the two maps (the basis of which is a digital database), the newest overview surface geological map (1:500,000) of Hungary was created (with appropriate merging according to the scale) (Gyalog 2013). This map was published 30 years after the mapping of Fülöp et al. (1984); it depicts the geological formations of Hungary not by their lithological characteristics, but on the basis of their respective lithostratigraphic bases, as approved by the Hungarian Stratigraphic Commission. Lithostratigraphic units older than Pleistocene, as well as Pleistocene and Holocene formations were considered alongside integrated stratigraphic, facies, genetical and distribution information.

According to this, in contrast with former practice, the explanatory book of the map is not limited to the brief description of the lithology and the palaeontology. It contains the description of the lithostratigraphic units according to our current knowledge, revealing also the relationship of one unit to the other. The book is special also from another aspect: experts of the respective geological ages were asked to write the chapters of the explanatory book; however, they did not participate in the compilation of the map. As a consequence, there are some theoretical contradictions in connection with the aggregation and depiction of several formations; these points are explained along with the descriptions of the formations. A typical problem was that some important formations are not shown on the maps due to the small scale used and the aggregations. These rock units are described in the explanatory book and are marked with a superscript star after the name of the formation (for example *Pisznice Limestone**). The authors of the explanatory book put the most recent stratigraphic results in the descriptions. These results, however, were changing even during the time of the writing and compilation of the book. At the right place, mostly due to the stratigraphic modifications affecting the Miocene chapters (for example at the beginning of

chapter Upper Miocene), a brief description of the changes is attached to the given stratigraphic units. Where the new results have not been published yet, but have been already approved by the stratigraphic working groups, we refer to them with "personal communication".

The surface geological explanatory book is related to the explanatory book "Geology of the pre-Cenozoic basement of Hungary", published at the end of 2014 (HAAS, BUDAI eds 2014). As a consequence, the description of the surface pre-Cenozic formations is less detailed than that of the Cenozoic formations. A detailed description of the pre-Cenozoic units and the interpretation of the relationships are found in the work of HAAS, BUDAI ed. (2014).

The two new explanatory books made for the newest, 1:500,000-scale geological maps are the most complete and most recent summaries of the geology of Hungary. Their combined use provides fresh and concise geological information on the geology of Hungary.

Geological build-up of the regions of Hungary

DUNÁNTÚLI-KÖZÉPHEGYSÉG (TRANSDANUBIAN RANGE)

The SW–NE-striking ridge of the Transdanubian Range stretches from the Keszthely Mountains up tothe Pilis–Visegrád Mountains (Figure 1). It is dominantly made up of Triassic formations (Figure 2), the total thickness of which reaches 3 kilometres. Older, Palaeozoic formations crop out from below the Triassic successions in the area of the Balaton Highlands, and the Balatonfő and Velence Mountains. Younger, Mesozoic (Jurassic and Cretaceous) formations cover larger areas in the upland regions of the Bakony and the Gerecse.
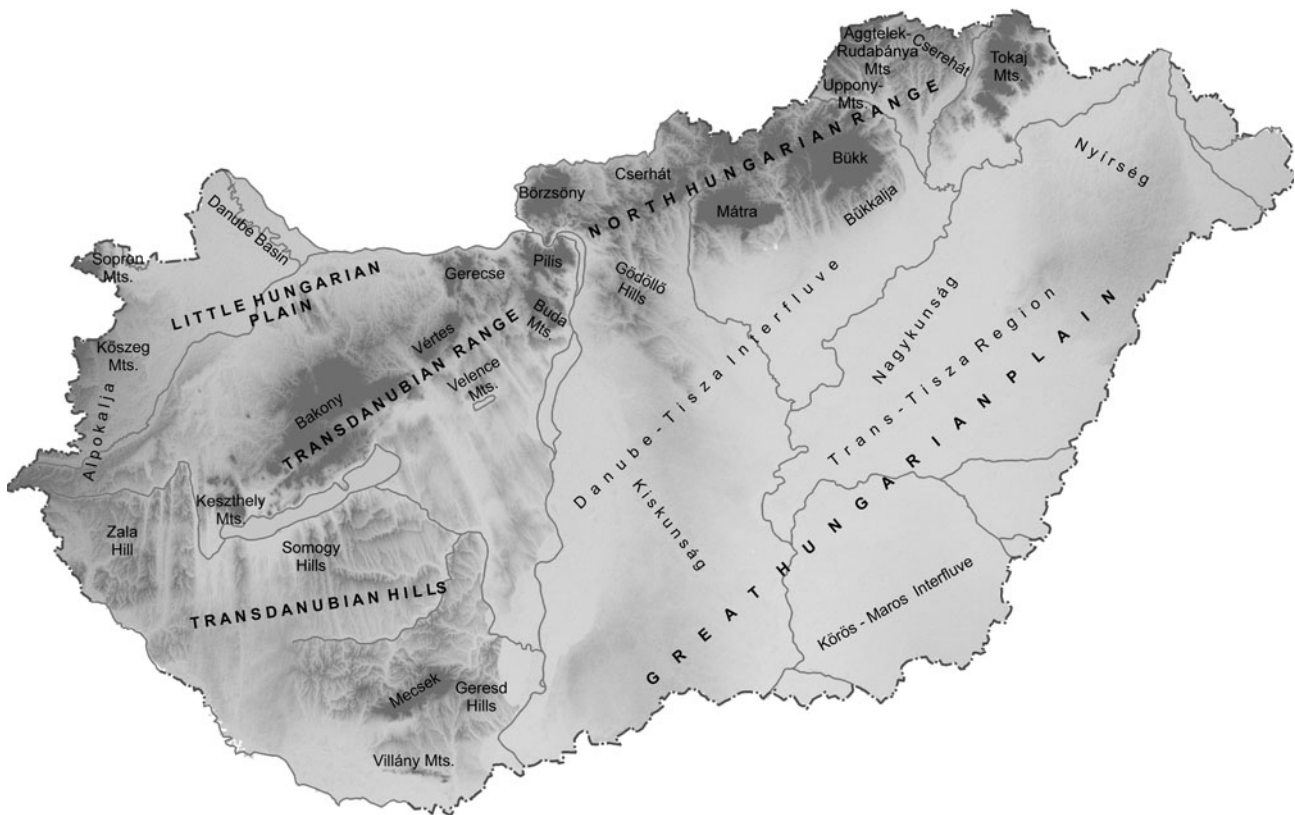
Figure 1. Map of the regions of Hungary

The *Keszthely Mountains* rise at the south-western end of the Transdanubian Range and are made up of Upper Triassic shallow marine dolomite and limestone. Basaltic mezas occur in the Zalaszántó–Várvölgy Basin (in the northern foreland of the mountains) and in the Tapolca Basin. These remnant hills rise from the loose, Miocene sediments of their surroundings.

The *Bakony* region forms the south-western part of the Transdanubian Range. It has a prolonged (in a NE–SW direction) bowl-shaped (syncline) structure made up of Palaeozoic and Mesozoic rocks, the south-eastern limb of which crops out in

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Figure 2. Precenozoic on the surface in the Transdanubian Range (after Haas, Budai eds 2014 modified)

Legend: 3P – Balatonfelvidék Sandstone, 20T – Köveskál Dolomite, Arács Marl, Hidegkút, Csopak Fm, 17T – Aszófő Dolomite, Iszkahegy Limestone, 16T – Megyehegy Dolomite, Tagyon Fm, 12T – Felsőörs Limestone, Vászoly Fm, Buchenstein Fm, Füred Limestone, 11T – Budaörs Dolomite, 5T – Veszprém Marl, Csákberény Fm, Sándorhegy Fm, 4T – Sédvölgy Dolomite, Gémhegy Dolomite, Ederics Limestone, Main Dolomite, 3Ta – Rezi Dolomite, 3Tb – Kössen Fm, 2T – Dachstein Limestone, 1T – Mátyáshegy Fm, Csővár Limestone, 6Ja – Kardosrét Limestone, 6Jb – Pisznice, Isztimér, Kishát, Törökbükk Limestone, 6Jc – Hierlatz Limestone, 6Jd – "ammonitico rosso", Tűzkövesárok Limestone, Kisgerecse Marl, Tölgyhát Limestone, 2Ja – Lókút Radiolarite, 2Jb – Pálihálás Limestone, 2Jc – Szentivánhegy Limestone, 2Jd – Mogyorósdomb Limestone, 8Ka – Bersek Marl, 8Kb – Lábatlan Sandstone, 7Ka – Tata Limestone, 7Kb – Zirc Limestone, Környe Limestone, 6Ka – Tés Clay Marl, 6Kb – Vértessomló Siltstone, Pénzeskút Marl, 4K – Csehbánya Fm, Ajka Fm., 3K – Ugod Limestone, 2K – Jákó, Polány Marl
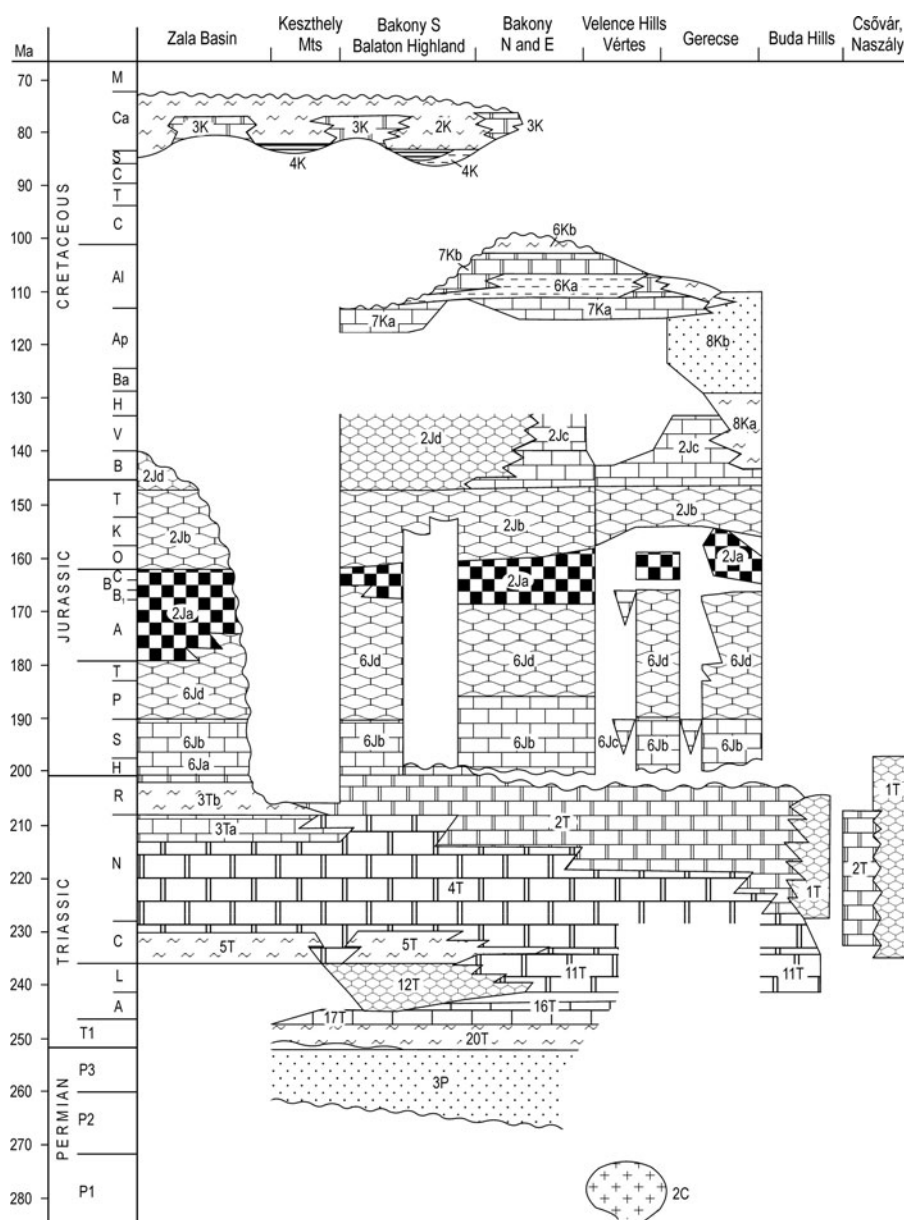
the area of the Balaton Highlands. In the axis of the syncline Jurassic and Cretaceous formations are deposited. The Palaeogene and Miocene sediments cover large areas in the inter-mountain basins and on the Little Plain, which is the foreland of the mountains.

The Carboniferous granite, which forms part of the crystalline basement of the Transdanubian Range, crops out in the *Velence Mountains*. The granite is enfolded by older Palaeozoic metamorphic rocks. The northeastern part of the mountains is made up of Eocene andesite.

The northeastern ridge of the Transdanubian Range comprises the Vértes, the Gerecse, the Buda Hills, the Pilis and the Visegrád Mountains. The *Vértes Mountains*, which are primarily made up of Upper Triassic dolomite, are separated from the Bakony by the Mór Trench. Its northern foreland is covered with Palaeogene (Eocene and Oligocene) sediments, while those in its southern foreland are Upper Miocene (Pannonian). The main mass of the Gerecse is made up of Triassic shallow marine limestone, while the younger Mesozoic (Jurassic–Cretaceous) formations are dominantly known to occur in the northern part of the mountains. Thicker Palaeogene formations occur on the area of the Tatabánya and the Dorog Basins, which represent the southern and eastern forelands of the mountains. The bulk of the *Buda* and the *Pilis Mountains* is made up of Upper Triassic shallow marine dolomite and limestone. In the Buda Hills the Upper Eocene and the Oligocene formations cover larger areas, while the occurrence of the Miocene sediments is restricted to the forelands of the mountains. The *Visegrád Mountains* is situated at the northeastern ending of the Transdanubian Range. In a geological sense, it already belongs to the Miocene volcanic arc of the North Hungarian Range.

ÉSZAKI-KÖZÉPHEGYSÉG (NORTH HUNGARIAN RANGE)

The western part of the Miocene volcanic arc of the North Hungarian Range is represented by the *Börzsöny Mountains*, the geology of which is similar to that of the Visegrád Mountains; the latter are separated from the former by the Danube. The geology of the two mountain regions is characterised by the alternation of Middle Miocene andesite and dacite lava rocks and pyroclastic rocks (agglomerate, tuff). The middle section of the Miocene andesite volcanic arc is represented by the *Cserhát Hills* and the *Mátra Mountains* to which, in the north, the basalt area of the *Karancs–Medves* upland region joins. The Miocene andesite and the Pliocene basalt overlie (and penetrate) the older (Oligocene and Miocene) clastic sedimentary formations.

The block of the *Bükk Mountains* wedges into the Miocene volcanic wreath of the North Hungarian Range. It is made up of sedimentary rocks. The oldest, Palaeozoic formations crop out in the northern part of the Bükk (North Bükk Anticline) and north of it, in the Uppony Mountains (Figure 3). Most parts of the Bükk Plateau are made up of thick Middle–Upper Triassic shallow marine carbonates, which alternate with deep marine sediments in the south-eastern part of the Bükk. The south-western part of the Bükk region is dominantly made up of Jurassic deep marine clastic sediments and magmatic rocks (Figure 4). During the Cretaceous– Palaeocene the rock mass making up the region was intensively folded and foliated. As a result of the uplift, the area was affected by significant denudation. Palaeogene marine sediments occur on the south-western margin of the mountains. The southern foreland of the mountains (Bükkalja– Bükk foothills) is mostly covered with Miocene volcanic rocks, with shallow marine sediments overlying them. The Bükk and the Mátra regions are bordered by Miocene sediment-filled basins in the north (Borsod Basin and Nógrád Basin).

The *Aggtelek Karst* and the *Rudabánya Mountains* are situated in the north-eastern part of the North Hungarian Range. They are mostly made up of Mesozoic sedimentary rocks and have a rather complicated structure (Figure 5). The Szendrő
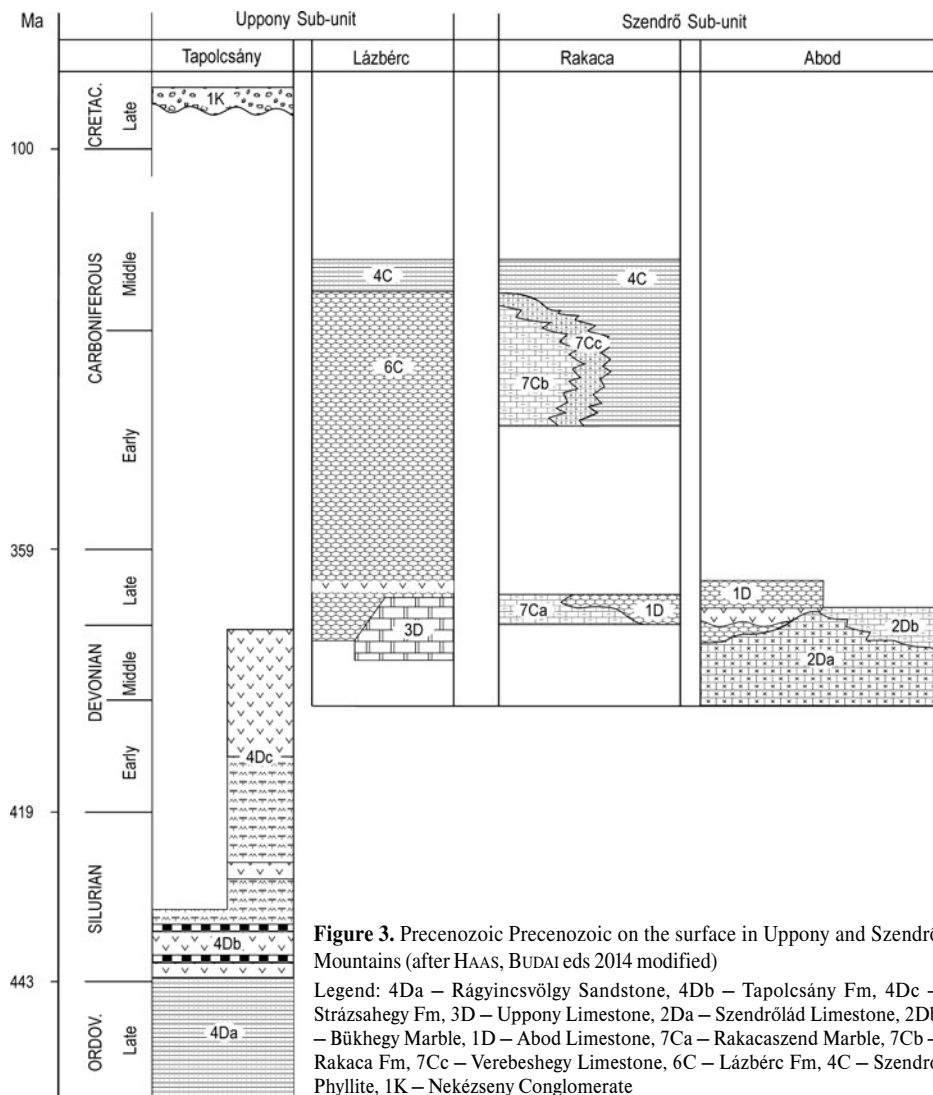
Figure 3. Precenozoic Precenozoic on the surface in Uppony and Szendrő Mountains (after Haas, Budai eds 2014 modified)

Legend: 4Da – Rágyincsvölgy Sandstone, 4Db – Tapolcsány Fm, 4Dc – Strázsahegy Fm, 3D – Uppony Limestone, 2Da – Szendrőlád Limestone, 2Db – Bükhegy Marble, 1D – Abod Limestone, 7Ca – Rakacaszend Marble, 7Cb – Rakaca Fm, 7Cc – Verebeshegy Limestone, 6C – Lázbérc Fm, 4C – Szendrő Phyllite, 1K – Nekézseny Conglomerate

Figure 4. P Precenozoic on the surface in the Bükk Mountain (after HAAS, BUDAI eds 2014 modified)

Legend: 4C – Szilvásvárad Fm, 3C – Mályinka Fm, 4Pa – Szentlélek Fm, 4Pb – Nagyvisnyó Limestone, 20T – Gerennavár Limestone, 16T – Hámor Dolomite, 15Ta – Szentistvánhegy Metaandesite, 15Tb – Várhegy Fm, 11T – Berva, Fehérkői, Bükkfennsík, Kisfennsík Limestone, 8T – Létrás and Szinva Metabasalt, 7T – Hegyestető Fm, Felsőtárkány Limestone, 4Ja – Bányahegy Radiolarite, 4Jb – Lökvölgy Fm

Mountains, which belongs to the *Cserehát*, are made up of slightly metamorphic Palaeozoic sedimentary rocks. The forelands of the mountains are covered with young, Miocene (Pannonian) clastic sediments.

The *Tokaj Mountains* represent the north-eastern part of the Miocene volcanic arc of the North Hungarian Range. This range is made up of Middle and Upper Miocene rhyolite, andesite and dacite. It is bordered by the Hernád River in the west, and by the valley of the River Bodrog in the east.

THE MECSEK AND THE VILLÁNY HILLS

The two inselbergs of the South Transdanubian region are the Mecsek and the Villány Hills (Figure 6). The oldest surface formations of the *Mecsek* (Palaeozoic metamorphic rocks, Carboniferous granite) are known to occur in the eastern part of the mountains, in the area of the Geresd Hills.
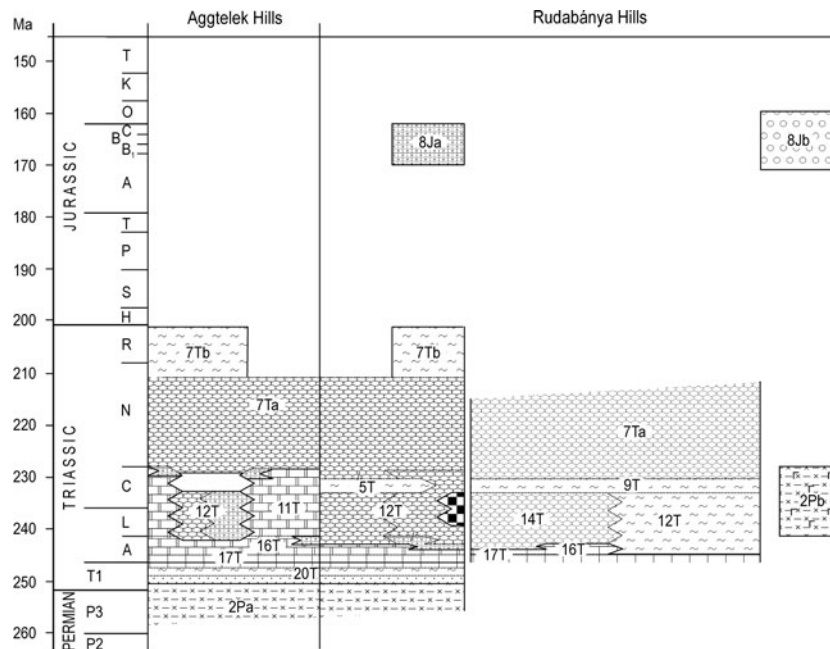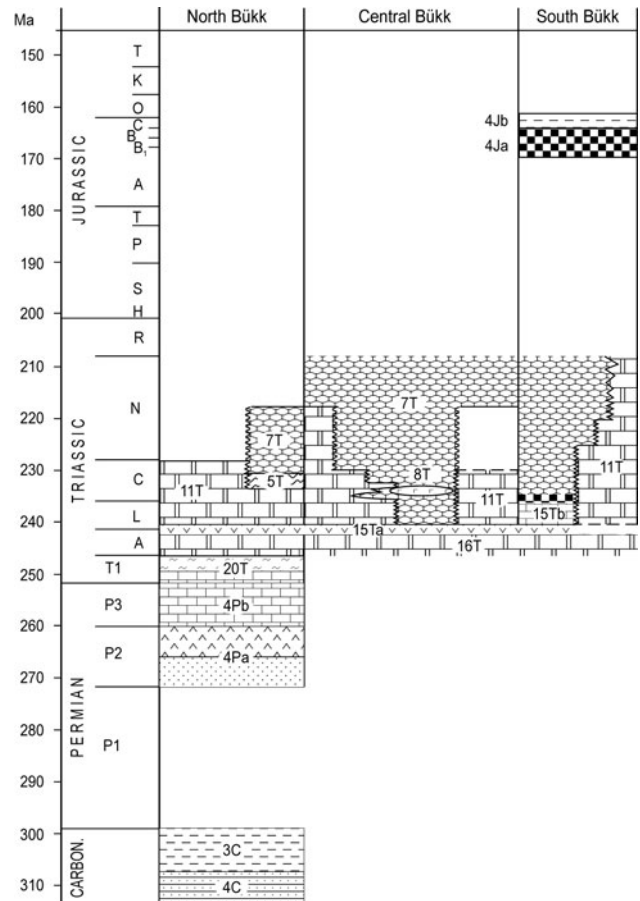
Figure 5. Precenozoic on the surface in the Aggtelek and Rudabánya Hills (after HAAS, BUDAI eds 2014 modified)

Legend: 2Pa – Hídvégardó Complex, Perkupa Anhidrite, 2Pb – Bódvavölgy Ofiolite, 20T – Bódvaszilas Sandstone, Szin Marl, Szinpetri Limestone, 17T – Gutenstein Fm, Rudabánya iron ore-bearing beds , 16T – Steinalm Limestone, 14T – Szentjánoshegy Limestone, 12T – Dunnatető Limestone, Bódvarákó Fm, Bódvalenke Limestone, Szárhegy Radiolarite, Reifling, Derenk, Nádaska Limestone, 11T – Wetterstein Limestone, 9T – Tornaszentandrás Slate, 7Ta – Hallstatt, Pötschen, Nagykő Limestone, 7Tb – Zlambach Marl, 8Ja – Telekesvölgy Complex, 8Jb – Telekesoldal Complex

The western part of this mountain area is a large anticline (West Mecsek Anticline), composed of thick Permian – Lower Triassic clastic sedimentary rocks, Middle Triassic carbonates, as well as Upper Triassic clastic rocks.

In contrast with this, the bowl-shaped structure of the eastern part of the Mecsek is dominantly built up of Jurassic clastic and carbonatic sedimentary rocks, and Lower Cretaceous volcanic rocks (East Mecsek Syncline); this is the same as the northern structure of the mountains (known as the "Northern Sliver"). In the middle part of the mountain, Lower Miocene andesite can be found, while in the northern foreland Miocene sediments have significant surface occurrences. The structure of the *Villány Mountains* is made up of a series of slivers, which have shifted one onto the other. In this rock series Middle and Upper Triassic, Jurassic and Lower Cretaceous carbonate successions are repeated. The surroundings of the two mountains are covered with Quaternary sediments.

DUNÁNTÚLI-DOMBSÁG (TRANSDANUBIAN HILLS)

The Transdanubian Hills comprises the Somogy Hills south of Lake Balaton, and west of it, the Zala Hills. In both areas Late Miocene (Pannonian) sediments represent the oldest surface formations and these are covered with large areas of loess. The characteristic formation of the area between the two hilly regions is the fluvioeolian sand.

KISALFÖLD (LITTLE HUNGARIAN PLAIN) AND ALPOKALJA

The bulk of the *Little Hungarian Plain* is covered with the fluvial sediments of the River Danube and the River Rába. The thickness of these sediments is locally significant (several hundreds of metres). The area is bordered by the Alpokalja region in the west and the Transdanubian Range in the south-east. At the foot of the hills mostly Upper Miocene (Pannonian) clastic sediments occur. Along the margin of the Little Plain, at the foot of the Bakony, several smaller basalt bodies can be found.

The foothills of the Eastern Alps in Hungary are built up of nappes. These foothills are represented by metamorphic rocks which crop out along the western border, in the area of the *Alpokalja*. The Sopron Mountains are made up of gneiss and mica schist, while the Kőszeg Mountains consist of Jurassic–Cretaceous metamorphic rocks. The crystalline rocks are enclosed by young, Miocene and Quaternary sediments which can be found in the forelands of the mountains.

ALFÖLD (GREAT HUNGARIAN PLAIN)

Most parts of the *Great Hungarian Plain* are covered with Quaternary, loose, clastic sediments. The Pleistocene succession is dominantly made up of fluvial sediments, which are composed of cyclically alternating gravel, sand, silt and clay. The thickness of the succession varies in the different parts of the Great Hungarian Plain; for example, in the Jászság Basin, its thickness is 400m (in the Makó Trench) but it may attain 1200m in other areas. The Upper Pleistocene loess is primarily characteristic on the mountain margins of the basins of the Great Hungarian Plain and on the Mezőföld, while the Upper Pleistocene – Holocene wind-blown sand mostly occurs in the Danube–Tisza Interfluve (Kiskunság) and in the Nyírség. Holocene sediments are represented by the floodplain sediments of the rivers and the characteristic formations of alkaline areas.

Figure 6. Precenozoic on the surface in the Mecsek and Villány Mountains (after Haas, Budai eds. 2014 modified)

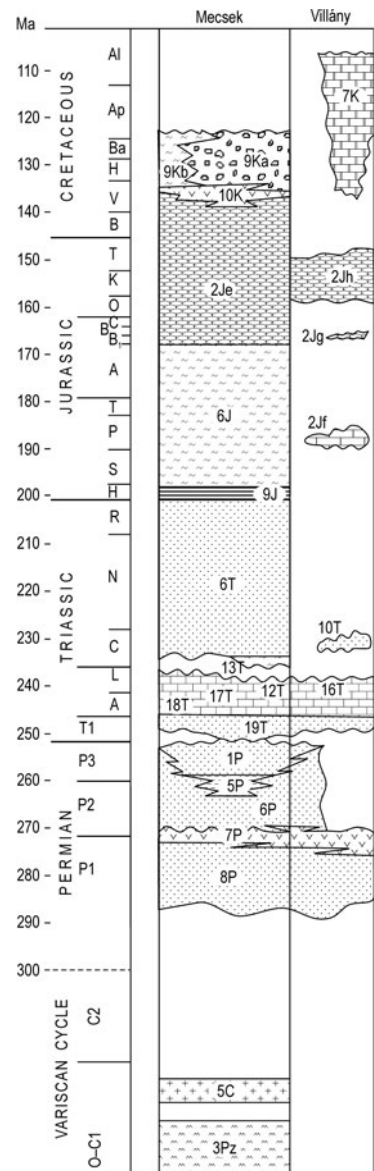Legend: 3Pz – Ófalu Group, 5C – Mórágy Granite, 8P – Korpád Sandstone, Kásó Fm, 7P – Gyűrűfű Rhyolite, 6 P – Cserd Fm, 5P – Boda Claystone, 1P – Kővágószőlős Sandstone, 19T – Jakabhegy Sandstone, 18T – Patacs Siltstone, 17T – Hetvehely Fm, Víganvár Limestone, Rókahegy Dolomite, Lapisi Limestone, 16T – Csukma Fm, Templomhegy Dolomite,13T – Kantavár Fm, 12T – Zuhánya Limestone, 10T – Mészhegy Fm, 6T – Karolinavölgy Sandstone, 9J – Mecsek Coal, 6J – Vasas Marl, Hosszúhetény Calcareous Marl, Mecseknádasd Sandstone, Kecskehát Limestone, Rékavölgy Siltstone, Komló Calcareous Marl, 2Je – Óbánya, Fonyászó, Kisújbánya, Márévár Limestone, 2Jf – Somssichegy Limestone, 2Jg – Villány Limestone, 2Jh – Szársomlyó Limestone, 10K – Mecsekjánosi Basalt, 9Ka – Magyaregregy Conglomerate, 9Kb – Hidasivölgy Marl, Apátvarasd Limestone, 7K – Nagyharsány Limestone

Geological description of the superficial formations of Hungary

PALAEOZOIC (UNDIVIDED)

Mica schist, gneiss, amphibolite (Vilyvitány Mica Schist — 4Pz)

Metamorphites occurring in the northern part of the Tokaj Mountains (Tokaji-hegység) include medium- and high-grade disthene, staurolite and sillimanite mica schists, and paragneisses. One can also observe amphibolite intercalations (FÜLÖP 1994). Locally the rocks show signs of mylonitization; the bulk of these rocks have undergone high-grade kaolinization, sericitization and sideritization. Their thickness is unknown. The radiometric age, 312 Ma, marks the time period of the metamorphism.

Gneiss, quartz phyllite, crystalline limestone, serpentinite, amphibolite (Ófalu Group — 3Pz)

The tectonic zone of the Mecsekalja Belt is situated south and east of the Mecsek Mountains and is made up of metamorphised tectonic mega-breccia; in the latter phyllite, amphibolite, serpentinite and gneiss, as well as crystalline limestone and metasandstone occur (FÜLÖP 1994, BALLA, GYALOG eds 2009). The rock body has a tectonic contact with the Mórágy Granite, as well as with the Lower Jurassic series of the East Mecsek.

Gneiss; metagranite, amphibolite (Sopronbánfalva Gneiss, Fertőrákos Crystalline Schist, Gödölyebérc Amphibolite — 2Pz)

Foliated gneiss (biotite-muscovite gneiss) can be found in the crystalline schist series of the Soproni-hegység (Sopron Mountains). This formed as a result of the alteration of the granite body that was injected into the Palaeozoic sedimentary rock succession (*Sopronbánfalva Gneiss*). The quantity of the amphibolite and the leucophyllite (quartz–muscovite schist) is less; they occur as lenses or are bound to certain horizons. Probably, their original material was basic volcanic rock (*Gödölyebérc Amphibolite*) (FÜLÖP 1990, LELKESNÉ FELVÁRI 1998). The outcropping metamorphites in the vicinity of Fertőrákos are amphibolite schists, mica schists and gneisses (*Fertőrákos Crystalline Schist*). The first metamorphic event took place 280–300 million years ago. It was followed by another, ca. 70–80 million years ago (Alpine Orogenesis).

Mica schist, amphibole schist, muscovite schist, phyllite, leucophyllite, quartz schist (Óbrennberg, Vöröshíd Mica Schist, Füzesárok White Schist — 1Pz)

The largest part of the mass of the Sopron Mountains is made up of polymetamorphic mica schists. The protoliths of these schists were sedimentary rocks that were affected by metamorphism during the Variscan orogeny, ca. 280-300 million years ago (FÜLÖP 1990, LELKESNÉ FELVÁRI 1998).

ORDOVICIAN–SILURIAN

Quartz phyllite, chlorite–muscovite schist; gneiss (Balatonfőkajár Quartz Phyllite — OS)

A greenschist facies rock body crops out on the area of Balatonfő. It comprises grey, greenish grey quartz phyllite, quartzite and chlorite–muscovite schist, accompanied by carbonate-quartz phyllite, albite gneiss and graphitic schist. It is highly foliated.

According to borehole data, its thickness reaches hundreds of metres. There is no information on its age, but on the basis of lithostratigraphic estimates it can be assigned to the Ordovician–Silurian (Fülöp 1990, Lelkesné Felvári 1998, Budai et al. 1999).

ORDOVICIAN–DEVONIAN

Slate, metasiltstone, metasandstone (Lovas Slate — OD)

The largest part of the Early Palaeozoic succession of the Transdanubian Mountains is made up of an anchimetamorphic rock series comprising grey, greenish grey slate, metasiltstone and metasandstone, as well as siliceous shale lenses (*Lovas Slate*). In several horizons the intercalations of acidic (*Alsóörs Metarhyolite**), basic (*Litér Metabasalt**), and neutral metavolcanic (*Révfülöp Metaandesite**) bodies can be seen. In most cases the rock series is highly folded (sometimes, overturned). The substratum is unknown. The overlying formation is Upper Permian sandstone; this has been deposited with a significant hiatus and erosional unconformity. The maximal as-drilled-thickness of the formation exceeds 1000m. It occurs on the surface in the Balaton Highland (Révfülöp, Alsóörs) and in the northern part of the Velence Mountains (Pátka, Szűzvár, Nadap). According to the fossil records (acritarchs, graptolites, conodonts), its age is Ordovician–Devonian (Fülöp 1990, Lelkesné Felvári 1998, Budai et al. 1999, Gyalog, Horváth eds 2004).

SILURIAN–DEVONIAN

Microgabbro, metabasalt (Bencehegy Microgabbro — SD)

A dark greenish grey, basic, holocrystalline, ophitic-textured subvolcanic dyke is known to occur only in the eastern part of the Velence Mountains. Its major mineral constituents are basic plagioclase, monoclinic pyroxene, green amphibole and magnetite. It is deposited in the upper part of the Lovas Slate and can be assigned to the Silurian–Devonian (Gyalog, Horváth eds 2004).

DEVONIAN

Shallow-marine sandstone, metasiltstone, open-marine shale, siliceous shale, basic metavolcanics (Csernelyvölgy, Rágyincsvölgy Sandstone, Tapolcsány, Strázsahegy Fm — 4D)

The lower section of the Early Palaeozoic succession of the Uppony Mountains is represented by fine-grained, foliated metasandstone (Figure 3, 4Da). It is made up of quartz grains and cemented by silica (*Rágyincsvölgy Sandstone*). It is accompanied by shale intercalations. It passes upward into massive or thick-bedded, silica-cemented, hard sandstone (greywacke); the latter contains shale, sandstone and phyllite clasts (*Csernelyvölgy Sandstone*). The thickness of the sandstone succession ranges between 100 and 200m. Given that it does not contain any fossils, it can be assigned to the Upper Ordovician solely on the basis of stratigraphic analogies (Fülöp 1994, Kovács 1998, Pelikán et al. 2005). Above the sandstone, deep marine turbidite follows, and this is composed of alternating dark grey shale and thinly-bedded siliceous shale (radiolarite). Locally, the formation contains basic volcanic (metabasalt) intercalations (*Tapolcsány Fm,* Figure 3, 4Db). It thickness can attain 400m. Due to the absence of horizon-marking fossils, it is assigned to the Silurian solely on the basis of stratigraphic analogies. The upper section of the Early Palaeozoic succession is made up of metabasalt, light grey, crinoidal limestone and metasomatic (ankeritic-sideritic) carbonate rocks (*Strázsahegy Fm,* Figure 3, 4Dc); olistostrome horizons can also be found in these rocks. According to conodonts, the age of the formation is Middle–Late Devonian (Fülöp 1994, Kovács 1998, Pelikán et al. 2005).

Shallow-marine crystalline limestone (Polgárdi, Uppony Limestone — 3D)

In the Balatonfő region, shallow marine, platform, dominantly thick-bedded, cyclic, white, crystalline limestone crops out (*Polgárdi Limestone*). The known maximum thickness of the formation exceeds 300m (borehole Szabadbattyán Szb–5). Its stratigraphic position is tectonic; the overlying formation is unknown and its assumed age is Middle Devonian, on the basis of badly preserved *Stromatoporoidea* fossils (Fülöp 1990, Horváth et al. 2004).

Light grey, unbedded or thick-bedded, shallow marine (platform) crystalline limestone is known to occur in the north-western part of the Uppony Mountains (*Uppony Limestone,* Figure 3). Its thickness is around 200m. In the absence of

fossils, only stratigraphic analogies can help to determine the age of the formation, which is reckoned to be Middle–Upper Devonian (FÜLÖP 1994, KOVÁCS 1998, PELIKÁN et al. 2005).

Marble, crystalline limestone, phyllite–metasandstone (Bükhegy Marble, Szendrőlád Limestone — 2D)

The most extensive formation of the Szendrő Mountains comprises coarse-crystalline marble (bioherm facies) and the basin facies of fine-crystalline limestone, and phyllite–metasandstone (*Szendrőlád Limestone,* Figure 3, 2Da). According to conodonts, the age of the formation is Middle–Late Devonian. Its thickness is around 400m. The Szendrőlád Limestone is overlain by bedded or massive, coarse-crystalline marble of carbonate platform facies (*Bükhegy Marble,* Figure 3, 2Db). The age of the formation is Middle–Late Devonian. Its thickness is ca. 200m (FÜLÖP 1994, KOVÁCS 1998).

Marine metatuffitic limestone (Abod Limestone — 1D)

Deposited onto the Devonian platform carbonate of the Uppony Mountains, greenish grey, thinly-bedded, pelagic basin limestone can be found. It contains chloritized basic metatuffite (cippolino), as well as black shale and metabasalt intercalations, and it has transverse foliation (Figure 3). Its thickness is around 200m. According to the rich condont fauna, its age is Late Devonian (FÜLÖP 1994, KOVÁCS 1998, PELIKÁN et al. 2005).

CARBONIFEROUS

Shallow-marine marble, sericitic limestone (Rakaca Fm, Verebeshegy Limestone — 7C)

The Upper Devonian carbonate platform succession of the Szendrő Mountains comprises white and bluish grey, banded, bedded or massive coarse-crystalline marble (*Rakacaszend Marble**) (FÜLÖP 1994, KOVÁCS 1998) (Figure 3, 7Ca). Its thickness is around 200m. The Lower–Middle Carboniferous marble (*Rakaca Fm,* Figure 3, 7Cb) has a similar facies. It interfingers with dark grey, fine-crystalline, conodont-bearing basin limestone (*Verebeshegy Limestone,* Figure 3, 7Cc).

Weakly metamorphosed limestone, fine-grained sandy siltstone; shale (Zobóhegyese, Lázbérc Fm — 6C)

The lowermost section of the Upper Carboniferous succession of the Bükk Mountains (in the north-east of Hungary) is made up of alternating black, clayey and fine sandy siltstone, and bedded–thick bedded grey sandstone (*Zobóhegyese Fm*). Into the latter 10–40m thick dark grey limestone bodies have been deposited. In certain horizons the sandstone is coarse-grained and silicified. The formation occurs only in the north-western part of the Bükk. In the north, it is connected to the Mályinka Formation along a steep tectonic plane. It is overlain by the Szilvásvárad Formation. Its thickness is estimated to be 600m. In the absence of fossils, it can be assigned to the lowermost part of the Upper Carboniferous solely on the basis of stratigraphic analogies (FÜLÖP 1994, PELIKÁN et al. 2005).

The Upper Carboniferous succession of the Uppony Mountains is made up of alternating dark grey, thin-bedded–bedded, recrystallised, pelagic basin limestone and grey shale (*Lázbérc Fm,* Figure 3). The thickness of the formation ranges between 200 and 300m. According to its rich conodont fauna record, it can be assigned to the lowermost Upper Carboniferous (FÜLÖP 1994, KOVÁCS 1998, PELIKÁN et al. 2005).

Weakly metamorphosed monzogranite, monzonite (Mórágy Granite — 5C)

The Mórágy Block (Geresd Hills) belongs to the East Mecsek mountain area. Its main mass is made up of monzogranite, accompanied by monzonite inclusions and leucocratic dyke rocks (Figure 6). The magmatic body, that locally shows signs of foliation, was affected by metamorphic effects of varying intensity. A smaller outcrop of the formation is known in the western part of the Mecsek, at Nyugotszenterzsébet. According to recent studies, the K-Ar radiometric age (~310–320 Ma) marks the time of the metamorphic event; magma injection occurred ca. 340–350 million years ago (FÜLÖP 1990, BALLA, GYALOG eds 2009).

Deep-marine sandstone, siltstone, clay, phyllite (Szilvásvárad Fm, Szendrő Phyllite — 4C)

The Variscan flysch, which outcropsin the area of the Szendrő Mountains, is made up of dark grey, black phyllite. In the latter there are also graded sandstone, metasandstone, limestone olistostrome and allodapic limestone horizons (*Szendrő Phyllite*). The material of the olistostromes has its main derivation from the Verebeshegy Limestone and the Rakaca Marble.

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According to the conodont fauna record, the formation can be assigned to the Upper Carboniferous (lower section). The thickness varies between 500 and 600m (Fülöp 1994, Kovács 1998, Pelikán et al. 2005).

A dark grey, black turbiditic rock series made up of cyclic sandstone, siltstone and clay crops out in the area of the anticline in the north-western part of the Bükk. It also contains small-grained polymict conglomerate and pebbly sandstone intercalations (*Szilvásvárad Fm,* Figure 4). As a result of anchizone metamorphism it has a foliated structure. Its thickness can exceed 1000m. It is overlain by the Mályinka Formation. According to stratigraphic analogies it can be assigned to the lower section of the Upper Carboniferous (Fülöp 1994, Pelikán et al. 2005).

Shallow-marine sandstone, siltstone, claystone (Mályinka Fm — 3C)

A Variscan molasse outcrops in the north-western part of the Bükk and in the Uppony Mountains (Figure 4). It is made up of a shallow marine clastic series, comprising alternating dark grey sandstone, siltstone and clay beds In this succession there are also conglomerate lenses and limestone bodies; the latter are represented by a diverse shallow marine fossil assemblage (algae, corals, crinoids and large foraminifera). The succession is foliated as a result of anchizone metamorphism. Its maximal thickness is 400m. It is assigned to the middle section of the Upper Carboniferous (Fülöp 1994, Kovács 1998, Pelikán et al. 2005).

Biotitic orthoclase granite; microgranite, granite porphyry, aplite (Velence Granite — 2C)

In the Transdanubian Mountains, the granite crops out in the area of the Velence mountain range (Figure 2). The calc-alkalic granite was consolidated at a hypabyssal depth. It contains pegmatite bodies, as well as microgranite and granite porphyry dykes. Its thickness is unknown; it is an intrusion in the Early Palaeozoic schist mantle. The radiometric age of the intrusion ranges between 260 and 320 Ma (according to recent measurements); the process of intrusion was also taking place in the Early Permian (274–282 Ma) (Gyalog, Horváth eds 2004).

Fluvial conglomerate, sandstone, siltstone, claystone (Füle Conglomerate — 1C)

The Variscan molasse facies of the Transdanubian Mountains is represented by a cyclic rock series in the Balatonfő region. This region consists of alternating grey conglomerate, sandstone and siltstone beds The bulk of the material of the grains is quartzite and quartzphyllite, as well as (rarely) metasandstone, metasiltstone, sericite schist and metarhyolite. Grey, dark grey, well-bedded clay and siltstone form thin intercalations in the formation. These intercalations have high organic carbon content and often contain carbonized plant fragments (*Calamites*) and coal bands. The stratigraphic position of the formation is unknown; according to the plant fragments and sporomorphs, its age is Late Carboniferous (Fülöp 1990, Majoros 1998, Budai et al. 1999).

PERMIAN

Fluvial conglomerate, sandstone, siltstone, clay (Korpád Sandstone, Kásó Fm — 8P)

In the west of the Mecsek Mountains the superficial occurrence of the Lower Permian fluvial clastic succession (molasse) is restricted to a smaller area. The succession is made up of fining-upward cycles of red conglomerate, sandstone and siltstone (*Korpád Sandstone*, Figure 6). The formation has been exposed by several boreholes in the area of the Villány Mountains and from an area between the Mecsek and the Villány Mountains. Its thickness is 100–700m. Its Early Permian age is justified by palynomorphs (Fülöp 1994, Barabás, Barabásné Stuhl 1998).

In the vicinity of Felsőregmec, in the northern part of the Tokaj Mountains, fluvial, greenish grey, grey and red sandstone, foliated siltstone, and small-pebbled conglomerates (*Kásó Fm*) occur; these are accompanied by rhyolite and rhyolitic tuff (7P–*Gyűrűfű Rhyolite*) intercalations (Fülöp 1994, Jámbor 1998).

Rhyolite, rhyolitic pyroclastic rock, tuffite (Gyűrűfű Rhyolite — 7P)

In the western foreland of the Mecsek, the Lower Permian rhyolite crops out over a small area. The rock is made up of brown, reddish brown, greyish lilac and green extrusive and subvolcanic lava rocks, accompanied locally by tuff and agglomerate intercalations (Figure 6). The formation frequently contains xenoliths of basement origin (metamorphite, Carboniferous and Permian sandstone). According to borehole data, from between the Mecsek and the Villány Mountains, the maximal known thickness of the formation is 830m. Its age is justified by radiometric data (Fülöp 1994, Barabás, Barabásné Stuhl 1998).

Fluvial sandstone, conglomerate, siltstone (Cserdi Fm — 6P)

The Middle Permian succession of the western foreland of the Mecsek is represented by cyclically alternating fluvial and fanglomerate-type conglomerate, and coarse-grained reddish brown sandstone (Figure 6). The material of the pebbles is mostly rhyolite and, albeit less frequently, granite or metamorphic rock. The maximum hickness of the drillings is around 1000m (Fülöp 1994, Barabás, Barabásné Stuhl 1998). The formation is denuded west of the Mecsek and it is known to occur at the southern boundary, in the Máriakéménd–Bár ridge.

Lacustrine claystone, siltstone (Boda Claystone — 5P)

The Middle Permian succession of the West Mecsek comprises playa lacustrine reddish brown siltstone, argillite and dolomite marl (Figure 6). There are also sandstone beds in the lower section of the formation. Its maximal thickness is around 1000m. Its extent is unknown; in the east it interfingers with the Cserdi Formation, as shown by the ore exploratory drillings near the city of Pécs. Its accepted age is justified by palynomorphs (Fülöp 1994, Barabás, Barabásné Stuhl 1998).

Shallow-marine limestone; sandstone, siltstone, evaporite (Nagyvisnyó Limestone, Szentlélek Fm — 4P)

The lower, ca. 100–300 m-thick section of the Upper Permian succession of the Bükk is made up of green, red, lilac-patched sandstone and siltstone. This succession is overlain by a 120–150 m-thick sabkha succession of alternating claystone, dolomite and gypsum–anhydrite (*Szentlélek Fm,* Figure 4, 4Pa). The uppermost part of the Upper Permian succession of the Bükk comprises thinly-bedded, black limestone, which also contains marl and calcareous marl intercalations. Frequently, in the lower section of the formation, dolomitized bodies occur (*Nagyvisnyó Limestone,* Figure 4, 4Pb). The formation was formed in an isolated lagoon. It occurs in the area of the North Bükk Anticline. It is highly pressed and is intersected with a dense calcite vein network. It has rich micro- and macrofauna, as well as microflora assemblages; according to the presence of this evidence its age is Late Permian. Its thickness is 300m (Fülöp 1994, Pelikán et al. 2005).

Fluvial sandstone, siltstone, conglomerate (Balatonfelvidék Sandstone — 3P)

The overwhelming part of the Upper Permian succession of the Transdanubian Mountains is a red, terrestrial, alluvial siliciclastic succession (Figure 2). The lower section of the rock series lies unconformably on the denuded surface of the Early Palaeozoic basement and is represented by coarse-grained formations (fanglomerate, conglomerate); however, the bulk of the succession is made up of cyclically alternating red sandstone and siltstone. It occurs on the surface in the south-western (Badacsonyörs and Zánka) part and in the north-eastern (between Aszófő and Balatonalmádi) part of the Balaton Highland. In can be followed on the Veszprém Plateau in the sliver north of the Litér Line, from Felsőörs up to Sóly. Its thickness ranges between 200 and 800m in the Balaton Highland; the thickness decreases to 50–150m towards the north-east. On the basis of the presence of sporomorphs, the age of the formation is Late Permian (Fülöp 1990, Majoros 1998, Budai et al. 1999).

Shallow-marine anhydrite, dolomite, marl; sandstone, siltstone, claystone (Perkupa Anhydrite, Hídvégardó Complex — 2P)

This slightly metamorphised complex (*Hídvégardó Complex*) occurs in the north-eastern part of the Rudabánya Mountains and is made up of shale, evaporite, and limestone and marl. Its thickness is 400–500m. The base of the Szilice succession of the Aggtelek–Rudabánya Mountains comprises a hypersalin lagoonal rock series of alternating anhydrite and marl, accompanied by variegated sandstone and siltstone beds (*Perkupa Anhydrite,* Figure 5, 2Pa). Into the upper section of the succession Triassic Bódvavölgy Ophiolite (Figure 5, 2Pb) blocks are tectonically kneaded. The thickness of the complex is 300m (Szentpétery, Less eds 2006).

Fluvial sandstone, conglomerate, siltstone, claystone (Kővágószőlős Sandstone — 1P)

The Upper Permian fluvial succession of the West Mecsek comprises upwardly-fining cycles of variegated conglomerate, pebbly sandstone, and siltstone and claystone beds In the upper part of the formation a uranium ore-bearing "green sandstone" facies appears (Figure 6). The uppermost member of the formation is known as the Tótvár Sandstone and extends over to the Lower Triassic. The total thickness of the formation is 150–1400m (Fülöp 1994, Barabás, Barabásné Stuhl 1998).

Shallow-marine marl, limestone, sandstone, dolomite (Lower Triassic sediments in the Bükk, Aggtelek and Bakony Mts. — 20T)

The Lower Triassic succession (Figure 2) of the Transdanubian Mountains crops out on the Balaton Highland, on the Veszprém Plateau and on the Iszka Hill (KOLOSZÁR et al. in HAAS ed. 1993, BUDAI et al. 1999, HAAS, BUDAI 2004). Its lower section is made up of grey, cavernous–cellular sandy dolomite, sandstone and dolomarl (*Köveskál Dolomite**); furthermore, as a partly heteropic facies of this succession, there is also a shallow marine marl series with thin limestone, dolomite and siltstone intercalations (*Arács Marl**). The thickness of the Induan succession ranges between 80 and 120m. It is overlain by the lower section of the Olenekian, represented first by red, thinly bedded–lamellar, fine sandy siltstone, and later, by thin–bedded, porous dolomite. The thickness of the formation is 80–100m (*Hidegkút Fm**). The bulk of the Olenekian Stage is represented by the Csopak Formation; the lower part of the latter comprises grey marl and Tirolite-bearing clayey limestone, the middle part red siltstone, while the upper part consists of greenish grey marl, sandy marl, calcareous marl and limestone (*Csopak Fm**).

The Lower Triassic succession of the Bükk Mountains (Figure 4) is known to crop out in the area of the northern anticline. Its lower section is made up of ooidic, laminated limestone (*Gerennavár Limestone**). Its thickness is 140m. It is overlain by the Olenekian succession, represented by variegated sandstone, laminated limestone, clay marl and calcareous marl (*Ablakoskővölgy Fm**). The thickness of the formation is around 300m (PELIKÁN in HAAS ed. 1993, VELLEDITS et al. 2004, PELIKÁN et al. 2005).

The lower part of the Lower Triassic succession of the Aggtelek–Rudabánya Mountains is made up of alternating shallow marine sandstone, siltstone and shale (*Bódvaszilas Sandstone**, Figure 5*)*. The thickness of the formation varies between 200 and 300m. Its age is Induan – Early Olenekian. The formation is overlain by a lagoonal succession of alternating grey, thinly-bedded marl, foliated clay marl and calcareous marl (*Szin Marl**). Its thickness is 300–350m. The uppermost section of the Lower Triassic is represented by grey, laminated, as well as thick-bedded, vermicular, subtidal lagoonal limestone (*Szinpetri Limestone**), the thickness of which is 150–300m. It is assigned to the Late Olenekian (KOVÁCS et al. 1988, 2004; SZENTPÉTERY, LESS eds 2006).

Fluvial red sandstone, conglomerate, siltstone (Jakabhegy Sandstone — 19T)

The Lower Triassic succession of the Mecsek and the Villány Mountains is represented by alluvial, delta and coastal-tidal flat red sandstone and conglomerate (Figure 6). At the base of the formation red, greyish red, compacted conglomerate and pebbly sandstone are deposited ("main conglomerate"); these are overlain by faded red, faded lilac, diagonally-bedded sandstone ("pebbly sandstone"), followed by a cyclic succession of "faded sandstone" and "reddish brown siltstone and sandstone". The characteristic cementing material is silica. The formation crops out only in the West Mecsek. In boreholes, however, it is known to occur not only in the Mecsek, but also in the area of the Mezőföld (in the northern foreland of the Villány Mountains), as well as in the basement of the Great Plain. Its thickness is 250m. The presence of sporomorphs indicates that its age is Early Triassic (BARABÁSNÉ in HAAS ed. 1993, TÖRÖK 1998, BÉRCZINÉ MAKK et al. 2004).

Shallow-marine siltstone, sandstone, claystone (Patacs Silstone — 18T)

The lowermost Anisian succession of the Mecsek and the Villány Mountains is dominantly made up of alternating red siltstone, red and green sandstone and green claystone. In the uppermost part of the succession the carbonate content increases (Figure 6). The formation gradually develops from the Jakabhegy Sandstone. The facies is shallow marine, flat coast. It crops out in the Mecsek and it is also known from boreholes in the Villány Mountains and between the two mountain ranges. The thickness of the formation ranges between 10 and 150m. According to palynology, it can be assigned to the Early Anisian (RÁLISCHNÉ FELGENHAUER, TÖRÖK in HAAS ed. 1993, BÉRCZINÉ MAKK et al. 2004).

Shallow-marine limestone, dolomite (Iszkahegy, Lapis Limestone, Aszófő Dolomite, Hetvehely, Gutenstein Fm, Rudabánya iron ore-bearing beds — 17T)

The Lower Anisian section of the Middle Triassic succession of the Transdanubian Mountains crops out from the Balaton Highland, and can be seen on the Veszprém Plateau and the Iszka Hill (Figure 2). The lower part of the succession is represented by light grey, micro-crystalline, laminated thinly-bedded, cellular dolomite (*Aszófő Dolomite*). Its facies is

hypersalin lagoonal and tidal flat sabkha. Its thickness varies between 200 and 250m. It gradually passes upwards into the dark grey, laminated, clayey, bituminous limestone; in its upper section the latter is thick-bedded (*Iszkahegy Limestone*). Its facies is lagoonal. Its thickness is around 250–300m but in the East Bakony and on the Iszka Hill the thickness is only 35–50m (BUDAI et al. 1999, HAAS, BUDAI 2004).

The Lower Anisian succession of the Mecsek and the Villány Mountains (Figure 6) is represented by cyclically alternating gypsum, anhydrite, dolomite and claystone. These rocks pass upward into dolomite and dolomite marl (*Hetvehely Fm*). The facies is coastal littoral and supra-littoral, sabkha, and also lagoonal. The thickness of the formation ranges between 80 and 200m. It is overlain by dark grey, thinly-bedded limestone, marl and foliated–lamellar claystone. In certain horizons lumachelle intercalations occur as well (*Víganvár Limestone**). The thickness of the limestone succession is 100m. It is overlain by a rock series comprising light red, thick-bedded dolomite and thinly-bedded, yellowish brown clayey dolomite beds (*Rókahegy Dolomite**). Its thickness in the Mecsek varies between 20 and 30m, but in the Villány Mountains it can attain as much as 100m. It is overlain by dark grey, small nodular, vermicular limestone, the lower section of which is thinly-bedded and dolomitic; the upper section is thick-bedded, bedded, and nodular (*Lapis Limestone*). The facies is a shallow marine carbonatic ramp. It appears on the surface in the West Mecsek, in the area of the Northern Sliver, as well as in the Villány Mountains. Its thickness is 80–300m (RÁLISCHNÉ FELGENHAUER, TÖRÖK in HAAS ed. 1993, BÉRCZINÉ MAKK et al. 2004).

The Lower Anisian succession of the Aggtelek–Rudabánya Mountains is represented by alternating dark grey or black, thinly-bedded/bedded bituminous limestone and dark grey, bedded bituminous dolomite, with thin (1–2cm) grey marl intercalations (*Gutenstein Fm,* Figure 5). The depositional environment was an oxygen-deficient lagoon and intertidal zone. The thickness of the succession is 250m (KOVÁCS et al. 1988, 2004; PIROS in HAAS ed. 1993; SZENTPÉTERY, LESS eds 2006).

The Lower Triassic sandstone (*Bódvaszilas Sandstone – 20T*) continuously passes upwards into marl and limestone (*Szin Marl – 20T*). In the Szin Marl, as well as in the Lower Anisian *Gutenstein Fm* (the deposition of which is also continuous), carbonatic siderite (with an average iron content of 20%)can be found; the latter formed as a result of sideritic metasomatism, related to acidic magmatism *(Rudabánya iron ore-bearing beds)* (SZENTPÉTERY, LESS eds 2006). The thickness of the formation can attain several hundreds of metres.

Platform limestone, dolomite (Tagyon, Steinalm Limestone, Megyehegy, Hámor Dolomite, Csukma Fm — 16T)

The lower section of the Middle Anisian, shallow marine carbonate complex of the Transdanubian Mountains (Figure 2) is represented by light grey, thick-bedded dolomite; thiswas deposited on a carbonate ramp (*Megyehegy Dolomite*). On one part of the area of the Anisian basin its thickness is only around 10 m; the maximal thickness varies between 250 and 300m. Middle Anisian platform carbonates occur in the middle part of the Balaton Highland, on the Veszprém Plateau and in the East Bakony (*Tagyon Fm*). The succession is made up of alternating light grey, bedded, biogene (Dasycladacean) subtidal lagoonal limestone (as well as dolomite) and laminated stromatolite. The thickness of the formation is 50–100m (BUDAI in HAAS ed. 1993; BUDAI et al. 1999; HAAS, BUDAI 2004).

The Lower–Middle Anisian shallow marine carbonate complex in the Bükk Mountains consists of grey, dark grey dolomite, unbedded or thick-bedded dolomite, laminated stromatolite beds and dasycladalean-, foraminifera- and gastropod-bearing layers (*Hámor Dolomite,* Figure 4). In the upper part of the formation, locally, coral limestone breccia of patch reef origin occurs. The thickness of the formation is around 400m (PELIKÁN in HAAS ed. 1993, VELLEDITS et al. 2004, PELIKÁN et al. 2005).

The Middle–Late Anisian shallow marine platform carbonate in the Aggtelek–Rudabánya Mountains (Figure 5) is represented by white or light grey, bedded–laminated, cyclic lagoonal limestone and unbedded reef limestone (*Steinalm Limestone*). The lagoonal limestone is characterised by a large number of dasycladaceans, while the reef limestone is distinguished by a significant amount of crinoids, brachiopods and calcareous sponges. The average thickness is 200–400m (KOVÁCS et al. 1988, 2004; PIROS, KOVÁCS in HAAS ed. 1993; SZENTPÉTERY, LESS ed. 2006).

The Middle Triassic platform carbonate in the Mecsek and in the Villány Mountains (Figure 6) is represented by thick-bedded limestone and dolomite, thinly-bedded clayey dolomite, and ooidic, crinoidal limestone (*Csukma Fm*). There are superficial occurrences of these rocks in the West Mecsek, in the Northern Sliver and in the Villány Mountains. Their respective thicknesses range between 100 and 370m; the age is Ladinian (RÁLISCHNÉ FELGENHAUER, TÖRÖK in HAAS ed. 1993, BÉRCZINÉ MAKK et al. 2004).

Metaandesite, -rhyolite, and its pyroclastics (Szentistvánhegy Metaandesite, Bagolyhegy Metarhyolite — 15T)

The Middle Triassic volcanic rocks in the Bükk Mountains are represented mostly by slightly metamorphic complexes comprising stratovolcanic neutral, andesite and volcanoclastic rocks (agglomerate, tuff, ignimbrite) (*Szentistvánhegy Metaandesite,* Figure 4, 15Ta). Subordinately, in the area of the North Bükk Anticline, rhyolite occurs as well (*Bagolyhegy*

Metarhyolite). The thickness is 350m and the age is Ladinian. On the area of the South Bükk the rhyolitic–dacitic lava and pyroclastic rock alternates with light grey limestone, on which alternating black marl and dark grey laminas are deposited; the latter are followed by claystone and sandstone with thin radiolarite intercalations (*Várhegy Fm**, Figure 4, 15Tb). The facies of the succession is lacustrine at the bottom while, in the upper section, it is isolated lagoonal and, finally, of a marine nature. The thickness is 60m. According to radiolarians, the age of the formation is Late Ladinian (Szoldán in Haas ed. 1993, Velledits et al. 2004, Pelikán et al. 2005).

<center>Middle–Upper Triassic</center>

Slightly metamorphosed marine limestone (Szentjánoshegy Limestone — 14T)

On the surface, the grey–light brown, banded, bedded small-crystalline, pelagic basin limestone occurs in the Torna Unit; this limestone has its deepest position among the units of the Rudabánya Mountains. Upsection, lilac red chert lenses are characteristic (Figure 5). The gradation of alteration is epimetamorphic. The thickness of the formation varies between 20 and 140m. Its age is Late Anisian – Early Carnian (Kovács in Haas ed. 1993; Kovács et al. 1988, 2004; Szentpétery, Less ed. 2006).

Sediments of restricted lagoon (marl, calcareous marl — Kantavár Fm — 13T)

The dark grey marl, calcareous marl succession crops out in the central part of the Mecsek and is characterised by its high content of organic matter (Figure 6). At the base there are bivalve lumachelles and large oncoids (*Kisrét Limestone**) . The depositional environment of the formation was at first a separating lagoon and later, a lake. Its thickness is 50–100m. The age is Late Ladinian – Early Carnian (Rálischné Felgenhauer, Török in Haas ed. 1993; Bércziné Makk et al. 2004).

Open-marine limestone, cherty limestone; shale, tuff (Felsőörs, Dunnatető, Zuhánya, Füred Limestone, Buchenstein, Bódvarákó Fm — 12T)

The Anisian – Lower Carnian pelagic basinal succession of the Transdanubian Mountains crops out on the Balaton Highland, on the Veszprém Plateau and on the Iszka Hill (Figure 2). Its lower section is made up of bedded, cherty limestone, brachiopod- and crinoid-bearing limestone, and bituminous laminated limestone (*Felsőörs Limestone*). The maximum thickness of the formation is 150m. On the Veszprém Plateau it is substituted by heteropic platform carbonates. The age of the formation is Middle–Late Anisian. It is overlain by tuff and calcareous or siliceous tuffite, accompanied by thinly-bedded limestone and dolomite intercalations (*Vászoly Fm**). Above it, bedded, nodular, greyish drab or faded red cherty limestone follows (*Buchenstein Fm*). Its thickness is 80m on the Balaton Highland and its age is Late Anisian – Ladinian. The pelagic basinal carbonate succession is topped by bedded, light grey, nodular limestone; in certain beds of this limestone there are dark grey chert lenses, and in its upper section there are marl intercalations (*Füred Limestone*). Its thickness is 20–30m. Its age is Late Ladinian – Early Carnian (Budai in Haas ed. 1993, Budai et al. 1999, Haas, Budai 2004).

The lower section of the Middle Triassic basinal succession of the Rudabánya Mountains (Figure 5) is made up of faded reddish grey, bedded–thick bedded limestone (*Dunnatető Limestone*). Its thickness ranges from 1–2m to nearly 100m. Its age is Late Anisian. Another facies is represented by alternating dark grey, well-bedded limestone and black chert beds. The succession also contains cherty dolomarl, siltstone, claystone and marl intercalations (*Bódvarákó Fm*). Its thickness varies but its maximum thickness is 40m. The age is Middle Anisian – Late Ladinian. The overlying pelagic basinal complex is represented by an alternation of thinly-bedded, red, lilac red, fine-crystalline–aphanic limestone, and light grey, white, coarse-crystalline "filamentous" limestone (bioclastite); this is accompanied by lilac red shale intercalations and red chert lenses (*Bódvalenke Limestone**). The thickness of the formation is several tens of metres. It is assigned to the Late Anisian – Late Carnian. The greenish yellow or dark grey–lilac red, thinly-bedded radiolarite is partially a heteropic facies of the above-mentioned formation. It contains dark grey shale laminas (*Szárhegy Radiolarite**). Its thickness is around 30m and its age is Ladinian–Carnian.

In the Aggtelek Mountains the Anisian platform is overlain by basinal grey, fine-crystalline limestone, in certain beds of which there are chert nodules (*Reifling Limestone**, Figure 5). The formation is assigned to the Late Anisian – Ladinian and its thickness is around 50m. A partially heteropic facies of the formation is the lilac grey, fine-crystalline, bedded–thick bedded or unbedded, brecciated limestone of slope or pelagic basin facies (*Derenk Limestone**, *Nádaska Limestone**). Its thickness is 50–100m and its age is Middle Anisian – Carnian (Kovács et al. 1988, 2004; Szentpétery, Less ed. 2006).

The pelagic outer shelf facies of the Middle Triassic marine succession of the Mecsek and the Villány Mountains is made up of grey, nodular limestone, calcareous marl with limestone nodules, brachiopod- and bivalve-bearing limestone, and calcareous marl (*Zuhánya Limestone*, Figure 6). The thickness of the formation is 50–100m in the Mecsek and 100–150m in the Villány Mountains. It is assigned to the Middle–Late Anisian (Rálischné Felgenhauer, Török in Haas ed. 1993, Török 1998, Bércziné Makk et al. 2004).

Shallow-marine platform limestone, dolomite (Wetterstein, Fehérkő, Berva, Bükkfennsík, Kisfennsík Limestone, Budaörs Dolomite — 11T)

The shallow marine platform carbonate facies of the upper section of the Middle Triassic succession of the Transdanubian Mountains (Figure 2) is represented by light grey, bedded, subtidal, dasycladalean-bearing dolomite; the latter is made up of cyclically-alternating, laminated, intertidal stromatolite beds (*Budaörs Dolomite*). It gradually thickens from the southern margin of the Veszprém Plateau north-eastward; in the Vértes Mountains and the Buda Hills it attains a thickness of up to1000m. Its age is Late Anisian – Ladinian (Haas 1993; Budai et al. 1999; Haas , Budai 2004).

The Middle–Upper Triassic, shallow marine platform carbonate facies of the Bükk (Figure 4) is represented by white or grey, cyclic, lagoonal and biogenic reef limestone in the southern part of the mountains (*Berva Limestone*). Its maximal thickness is 350m; its age is Ladinian – Early Carnian. In the area of the northern anticline the light grey, massive–bedded limestone is anchimetamorphic; in certain sections it shows Lofer cycle characteristics. Its thickness is around 400m (*Fehérkő Limestone*). The central part of the Bükk is made up of light grey, anchimetamorphic platform carbonate (*Bükkfensík, Kisfennsík Limestone*), the thickness of which attains 1000m; its age ranges from the Ladinian to the Rhaetian (Velledits in Haas ed. 1993; Velledits et al. 2004; Pelikán et al. 2005).

The Middle–Upper Triassic, shallow marine platform carbonate facies of the Aggtelek Mountains is represented by light grey, massive, reef limestone (with calcareous sponges, corals and hydrozoans), and thick–bedded, Lofer cyclic, lagoonal (locally dolomitized) limestone (*Wetterstein Limestone,* Figure 5). Its thickness is more than 1000m and itsage is Early Ladinian–Late Carnian (Kovács et al. 1988, 2004; Szentpétery, Less eds 2006).

Open-marine limestone, shallow-marine dolomite, marl, siltstone, sandstone (Triassic formations of the Villány Mountains together — 10T)

The Anisian section of the Middle–Upper Triassic succession of the Villány Mountains comprises shallow marine dolomite (*Rókahegy Fm — 17T*) and limestone (*Lapis Limestone — 17T*), and also basinal limestone (*Zuhánya Limestone — 12T*). The Ladinian stage is represented by shallow marine dolomite (*Csukma Fm — 16T*), onto which terrestrial clastic Carnian succession is deposited; the latter is made up of alternating sand, siltstone and clay (*Mészhegy Fm**)

<div align="center">UPPER TRIASSIC</div>

Open-marine clay shale, siltstone (Tornaszentandrás Shale — 9T)

In the Upper Triassic succession of the Torna Unit (the lowest-positioned unit of the Rudabánya Mountains) black, lamellar, pelagic shale and metasiltstone are deposited (Figure 5). The formation is cross-foliated and the gradation of its alteration is epimatemorphic. The maximal thickness is around 100m. According to conodonts, the age of the formation is Middle Carnian (Kovács et al. 1988, 2004; Szentpétery, Less eds 2006).

Extrusive and subvolcanic metabasalt (Létrás and Szinva Metabasalt — 8T)

In the eastern part of the Bükk Mountains highly deformed rock bodies made up of green, dark green metabasalt crop out, with siltstone, crinoidal limestone or cherty limestone intercalations. The volcanic sequence is deposited in a Middle–Upper Triassic basin limestone succession (Figure 4). Evidence of a thermal effect can be recognised at the contact zone on the top of the underlying limestone; the upper part of the volcanic formation is usually amygdaloidal. Limestone inclusions which have been affected by the thermal effect are frequently present. The rock has also been affected by the influence of epimetamorphism. Its maximum thickness is 50m and its age is Late Ladinian–Carnian (Szoldán in Haas ed. 1993, Velledits et al. 2004, Pelikán et al. 2005).

Open-marine limestone, cherty limestone, marl (Felsőtárkány, Répáshuta, Pötschen, Hallstatt, Nagykő Limestone, Hegyestető Fm — 7T)

One type of the Middle–Upper Triassic pelagic limestone succession of the Aggtelek–Rudabánya Mountains is represented by faded red, well-bedded, bedded, fine-crystalline limestone; this is accompanied by red chert nodules in the lower section (*Hallstatt Limestone,* Figure 5, 7Ta). The thickness of the formation in the Aggtelek Mountains can attain 150m, whereas in the Rudabánya Mountains it does not exceed 50m. According to the conodonts which are present, its age is Late Carnian – Norian. Another facies is represented by grey, thin-bedded, thin-layered cherty limestone. This limestone is characterised by undulating planes and marl intercalations and, in several horizons, with Halobia lumachelles (*Pötschen Limestone*). According to the conodonts of the formation, its age is Late Carnian – Middle Norian and its thickness varies between 50m and 100m. In the

Torna Unit the Pötschen Limestone is overlain by 20–30 m-thick, yellowish white or lilac red limestone. The limestone contains chert nodules (*Nagykő Limestone*). The age of the formation is Late Norian (KOVÁCS et al. 1988, 2004; SZENTPÉTERY, LESS eds 2006). The Late Norian–Rhaetian succession build up pelagic marl (*Zlambach Marl**, Figure 5, 7Ta).

The Middle–Upper Triassic pelagic succession of the Bükk Mountains (Figure 3 7T) in the northern anticline comprises dark grey metamarl, metasiltstone and bituminous limestone with silica nodules (*Hegyestető Fm*). The succession has undergone anchizone metamorphism. Its maximum thickness is 300m and its age is Ladinian–Carnian. The pelagic basin succession of the southern and eastern part of the mountains consists of grey, bedded cherty limestone, along with marl intercalations (*Felsőtárkány Limestone*). It is characterised by a folded structure; in several zones it is foliated and shows signs of anchizonal metamorphism. The thickness of the formation varies between 300 and 500m; its age is Carnian–Rhaetian (VELLEDITS et al. 2004, PELIKÁN et al. 2005).

Fluvial–lacustrine sandstone with pebbles, siltstone, claystone
(Karolinavölgy Sandstone — 6T)

The Upper Triassic succession of the Mecsek is made up of a terrestrial clastic rock series (Figure 6). The fluvial, delta and lacustrine succession is made up of alternating grey, small-pebbled sandstone, with siltstone and claystone beds cropping out in the central part of the Mecsek. The thickness of the formation is 400–600m and its age is Late Triassic (RÁLISCHNÉ FELGENHAUER, TÖRÖK in HAAS ed. 1993; BÉRCZINÉ et al. 2004).

Open marine marl; limestone; slate, metasiltstone, sandstone shale (Sándorhegy Fm, Veszprém,
Szőlősardó Marl, Vesszős Fm — 5T)

The Carnian fine-grained, clastic, basinal succession of the Transdanubian Mountains (Figure 2) is made up of grey clay marl and marl; clayey limestone and limestone intercalations occur as well (*Veszprém Marl*). The transition towards the heteropic platform carbonates is represented by brecciated bioclastic limestone and marl. Significant superficial occurrences are known on the Balaton Highland area: namely, in the South Bakony and also in the North Bakony. On the south-eastern margin of the Vértes the formation is substituted by calcareous marl, limestone, cherty–bituminous limestone, dolomarl and laminated dolomite (*Csákberény Fm**). The thickness of formation ranges between 30 and 800m. The lower section of the overlying shallow marine succession is made up of 35–70 m-thick, thick-bedded limestone and bituminous laminated limestone; the upper part is represented by cherty, oncoidic limestone, as well as calcareous marl and marl (*Sándorhegy Fm*). Large superficial occurrences are known on the Balaton Highland; subordinately, the formation also occurs in the Keszthely Mountains and in the North Bakony. Itsthickness varies between 100 and 120m and its age is Late Carnian (BUDAI et al. 1999, 2008; HAAS, BUDAI 2004).

The Carnian fine-grained, clastic basinal succession of the Bükk Mountains is made up of black slate and metasiltstone and, locally, brownish metasandstone (*Vesszős Fm,* Figure 4). Intercalating greenish, tuffaceous schist horizons are known at many places. At some stage the formation underwent high-temperature anchizonal metamorphism. It occurs on the surface on the southern side of the North Bükk Anticline and its thickness varies between 150 and 200m (VELLEDITS et al. 2004, PELIKÁN et al. 2005).

The Carnian fine-grained, clastic, basinal succession outcropping on the western side of the Rudabánya Mountains is represented by dark grey, pyritic clay marl and mottled marl, with grey–dark grey, fine-crystalline cherty limestone and calcareous marl intercalations (*Szőlősardó Marl,* Figure 5). The thickness of the formation is 80m; according to conodonts present in the succession, its age is Middle Carnian (KOVÁCS et al. 1988, 2004; SZENTPÉTERY, LESS eds 2006).

Shallow-marine platform dolomite, reef-limestone (Main Dolomite, Sédvölgy [Gémhegy]
Dolomite, Ederics Limestone — 4T)

On the overwhelming part of the Transdanubian Mountains (Figure 2) the Carnian shallow marine platform carbonates are represented by alternating bedded, thick-bedded and laminated dolomites (*Sédvölgy Dolomite*). Larger superficial occurrences are known in the Vértes and in the East Bakony. The lower and middle section is heteropic with the Veszprém Marl; the upper section interfingers with the Sándorhegy Limestone. The thickness of the formation is 400–500m. In the Keszthely Mountains light grey, unbedded or bedded biogene reef, as well as the ooidic–oncoidic limestone of a back reef facies are present (*Ederics Limestone*). The thickness of this section ranges between 100 and 250m.

Light grey platform dolomite has been deposited in the Carnian basin and on the platform formations in the Transdanubian Mountains. The rock is made up of cyclically alternating, thick-bedded lagoonal and lamellar tidal stromatolite bed groups (*Main Dolomite*). The Main Dolomite is the thickest and most extensive formation in the Keszthely Mountains, in the Bakony and in the Vértes. Its thickness is 1500m and itsage is Late Carnian – Norian (BUDAI et al. 1999, 2008; HAAS, BUDAI 2004).

Open-marine bituminous dolomite, limestone, marl (Kössen Fm, Rezi Dolomite, Feketehegy Fm — 3T)

The Norian–Rhaetian intraplatform basinal formations of the Transdanubian Mountains (Figure 2) are present in the Pilis, as well as in the South Bakony and in the Keszthely Mountains.

In the Pilis, the succession is made up of grey, brownish grey, thin-bedded or lamellar bituminous dolomite and limestone, with intercalating bivalve lumachelles (*Feketehegy Fm*). The formation is underlain by the Main Dolomite and overlain by Dachstein Limestone. Its thickness is 300m and its age is Middle – Late Norian (HAAS, BUDAI 2004).

The lower section of the Keszthely Mountains and the South Bakony is represented by grey, thin-bedded, lamellar, highly bituminous cherty dolomite, as well as bedded–thick bedded porous dolomite (*Rezi Dolomite,* Figure 2, 3Ta). The thickness of the formation varies between 100 and 300m; its age is Late Norian. Its overlying rocks are dark grey clay marl and marl; towards the heteropic platform the succession is accompanied by limestone intercalations (*Kössen Fm,* Figure 2, 3Tb). The thickness of the formation in the Keszthely Mountains is around 180 m; in the Bakony it decreases from SW to NE. Its age is Late Norian – Rhaetian (BUDAI et al. 1999, HAAS, BUDAI 2004).

Shallow-marine platform limestone (Dachstein Limestone — 2T)

The uppermost, Triassic, shallow marine platform carbonate complex of the Transdanubian Mountains is made up of light grey, thick-bedded limestone (Figure 2). In the lagoonal succession of the Bakony, the Vértes and the Gerecse, the subtidal beds cyclically alternate with laminated stromatolites and palaeosoil beds

In the Buda Mountains and in the area of the Duna-balparti rögök (Left Side Blocks of the Danube) the platform limestone is thick-bedded and oncoidic. The depositional environment is of a platform margin type. The limestone is underlain by the Main Dolomite; the transitional, lower section towards the dolomite is represented by limestone, dolomitic limestone, calcareous dolomite and dolomite. Thickness ranges between 700 and 1000m. Age is Late Carnian–Rhaetian (HAAS 1993, HAAS, BUDAI 2004).

Open-marine limestone, dolomitic limestone, dolomite (Csővár Limestone, Mátyáshegy Fm — 1T)

The Upper Triassic pelagic basin facies of the Transdanubian Mountains in the Buda Hills is represented by bedded, cherty limestone and dolomite, in which marl intercalations occur as well (*Mátyáshegy Fm,* Figure 2). The thickness of the formation is 200m. Its age is Carnian–Rhaetian.

In the area of the Duna-balparti rögök (Left Side Blocks of the Danube) the succession is made up of brownish grey, thinly-bedded bituminous limestone and dolomite. In several horizons there are also chert lenses (*Csővár Limestone*). Its redeposited facies is the toe-of-slope facies of the heteropic platform. The phylament and radiolarian facies indicate a deeper basin environment. The thickness of the formation is 600–700m and its age is Carnian–Early Liassic (HAAS 1993, HAAS, BUDAI 2004).

TRIASSIC–JURASSIC

Deep-marine shale, metasiltstone and metasandstone (Hidvégardó olistostrome — TJ)

This formaton is an olistostrome complex, cemented with greenish grey limestone. It crops out on a small area in the northern part of the Rudabánya Mountains. The lower section of the complex is made up of several metres-large limestone boulders, while the upper section consists of 20–30 cm-large limestone and radiolarite clasts (*Hídvégardó olistostrome*). The facies is deep marine slope debris or alluvial fan. Its assumed age is Triassic–Jurassic boundary and its maximum thickness is 15m (SZENTPÉTERY, LESS eds 2006).

TRIASSIC–CRETACEOUS

Triassic shallow marine limestone; Jurassic limestone; Cretaceous crinoidal limestone ("Tatai-rög": Dachstein Limestone, the whole Jurassic succession, Tata Limestone — TJK)

The "Tatai-rög" (Tata Block), located in the northern part of the Transdanubian Mountains (in the western foreland of the Gerecse highland) is made up of Upper Triassic Dachstein Limestone (2T), continuous Jurassic succession and Lower Cretaceous Tata Limestone (7K) (FÜLÖP 1975).

JURASSIC

LOWER–MIDDLE JURASSIC

Coastal–paludal–fluvial sandstone, claystone; black coal (Mecsek Coal — 9J)

The Late Triassic – Early Jurassic succession of the Mecsek is made up of alternating sandstone, foliated clay, and claystone (Figure 6). In the succession there are also black coal intercalations. The series, which is composed of three seam groups, consists of fluvial and delta marshy, as well as coastal marshy facies. The formation crops out on the area of the East Mecsek Syncline and the Northern Sliver. Its thickness ranges between 100 and 1200m, and it increases from NE to SW. The age of the formation is Rhaetian–Early Sinemurian (NÉMEDI VARGA 1998, SZENTE in FŐZY ed. 2012).

Deep-marine siliceous marl, shale, olistrostrome (Telekesvölgy, Telekesoldal Complex — 8J)

The Upper Triassic – Jurassic facies of the Rudabánya Mountains is represented by: (i) red and green, foliated claystone–clay marl–marl (ii) alternating grey, siliceous, crinoidal calcareous marl–clayey limestone and (iii) slate, and dark grey, manganic, radiolarian and sponge spicule-bearing, foliated claystone (*Telekesvölgy Complex,* Figure 5, 8Ja). The complex can be followed along the north-western side of the Rudabánya Mountains; the deposition of the complex is tectonic. Its thickness is around 450m and its age is Late Triassic – Middle Jurassic.

A Jurassic deep-marine complex (*Telekesoldal Complex,* Figure 5, 8Jb) crops out in the middle part of the Rudabánya Mountains, in the cut of the Bódva and, southwards, on the Telekesoldal. It consists of two units: (1) dark grey, black, siliceous marl, foliated claystone–slate with subordinately, black radiolarite and metarhyolite bodies; (2) two olistostrome horizons in the dark grey slate with sandstone, and also with limestone and rhyolite olistoliths. The total thickness of the complex is around 600m and its the age is Middle–Late Jurassic (DOSZTÁLY et al. 1998, SZENTPÉTERY, LESS eds 2006, GRILL in FŐZY ed. 2012).

Quartzite, sericite–chlorite phyllite (Kőszeg Quartz Phyllite — 7J)

The bulk of the Kőszeg Mountains is made up of quartz phyllite, metaquartzite and sericite–chlorite phyllite rocks. The greenschist facies formation is poorly foliated, thick-bedded, and lamellar-foliated/thinly-bedded. It has a clastic origin. The substratum is unknown; the overlying formation is Velem Calc-Phyllite. The thickness of the formation is 800–1000m. Its age has not been determined exactly but, conditionally, it is assumed to be Early–Middle Jurassic (LELKESNÉ FELVÁRI 1998; IVANCSICS in FŐZY ed. 2012).

Open-marine limestone, cherty limestone, marl, siltstone, sandstone (6J)

In the Bakony, the lower section of the Lower–Middle Jurassic succession of the Transdanubian Mountains is represented by white (upsection, pink-mottled), bedded, oncoidal platform limestone (*Kardosrét Limestone**, Figure 2, 6Ja). Its maximum thickness is 150m and its age is Hettangian. The characteristically faded red, yellowish white, bedded, intraclastic, poorly-layered limestone of the Gerecse is partly heteropic with the above-mentioned limestone. It contains crinoids and brachiopods and has stylolitic bed surfaces (*Pisznice Limestone**, Figure 2, 6Jb). It has subtidal facies. Its thickness ranges between 20 and 40m and the age of this formation is Late Hettangian–Pliensbachian. The characteristic facies of the continuous Jurassic succession of the Bakony is grey or red, bedded, cherty limestone (*Isztimér Limestone**). The thickness of the formation is 20–150m and itse is Hettangian–Sinemurian. The bedded or thinly-bedded, laminated, lenticular-structured red crinoidal limestone (*Kishát Limestone**, *Törökbükk Limestone**) is a typical facies in the Bakony and in the Gerecse. The limestone has a deep sublittoral slope or toe-of-slope facies. Its thickness is around 50 m; the age is Sinemurian–Pliensbachian. A typical filling of the Jurassic neptunean dykes is the red, yellowish white, light grey variegated biogene limestone. This limestone contains brachiopods and small ammonites, as well as crinoids and gastropods in rock-forming quantities (*Hierlatz Limestone**, Figure 2, 6Jc). It is poorly bedded or unbedded, and is often extraclastic. Its thickness ranges between 30 and 50m and the age of the formation is Late Sinemurian–Pliensbachian.

The Lower–Middle Jurassic red, nodular, clayey limestone and marl ("ammonitico rosso") is a characteristic rock type in the Transdanubian Mountains. It is present in the Pliensbachian Stage (*Tűzkövesárok Limestone**, Figure 2, 6Jd), in a part of the Toarcian (*Kisgerecse Marl**), and also in the Bathian (*Tölgyhát Limestone**). The facies is a pelagic basin and the total thickness in the continuous Jurassic sequences is 35m. The lamellar, reddish or yellowish grey, locally siliceous limestone, which contains pelagic bivalve shells in rock-forming quantities ("bositra limestone") (namely, *Eplény Limestone**), is partially heteropic with this limestone. The thickness of the formation ranges between 40 and 70m and its age is Toarcian–Callovian.

A local facies of the Bakony is the Toarcian carbonatic and oxidized manganese ore (*Úrkút Manganese Ore**). The thickness of this ore ranges between 1 and 50m (Vörös 1998).

The Lower–Middle Jurassic succession of the Mecsek (Figure 6) is represented by clastic rocks (Némedi Varga 1998, Raucsik in Főzy et al. 2012). The succession overlying the coal-bearing series consists of alternating sandstone, marl and calcareous marl *(Vasas Marl*)*. The facies is between shallow sublittoral and shallow bathyal. Significant superficial occurrences are mostly characteristic between Pécs and Komló. The thickness of the formation is 300–900m (thickness increases towards SW) and its age is Middle Sinemurian. The overlying "mottled marl" is made up of grey, dark grey, mottled, bedded, primarily silty calcareous marl (*Hoszúhetény Calcareous Marl**). The facies is between shallow sublittoral and shallow bathyal. It can be followed on the surface on the southern side of the East Mecsek in an uninterrupted line. The thickness of the formation ranges between 50 and 350m. and its age is Late Sinemurian–Early Pliensbachian. It gradually passes into a bedded, turbidite-origin siliceous sandstone and breccia complex (*Mecseknádasd Sandstone**), in which siliceous crinoidal limestone (*Kecskehát Limestone**) and black lamellar siltstone are deposited (*Rékavölgy Siltstone**). The thickness of the formation ranges between several tens of metres to 900m; its age is Pliensbachian–Toarcian. It continuously passes upwards into a cyclically alternating grey, mottled, bioturbated, ammonite-bearing silty marl, calcareous marl and clayey limestone succession. Its grain size and debris content decreases upwards in the succession. In the uppermost section there is laminated marl and clay marl (*Komló Calcareous Marl**). The facies is a hemipelagic basin. The formation occurs on the surface north and east of Komló. The thickness of the formation is between 20 and 240m and its age is Toarcian–Bajocian. Middle Jurassic crinoidal limestone there is between the Mecsek and Villány Mountains (*Máriakéménd Limestone**).

MIDDLE–UPPER JURASSIC

Gabbro, microgabbro, basalt (Tardos Gabbro, Szarvaskő Basalt, Hosszúvölgy Basalt — 5J)

The basic magmatites that crop out in the Bükk Mountains and in the area of the Darnó Zone have been formed as a result of basalt volcanism (to which gabbro intrusions are related).

The basic, subordinately ultrabasic magmatic rocks of the Darnó Hill are represented by gabbro; in thin bands one can also encounter olivine gabbro and wehrlite. Furthermore, there are smaller microgabbro bodies, as well as dolerite and basalt dykes. The upper section is made up of several hundred metres-thick basalt (in hyaloclastite, pillow lava and massive form); this alternates with several tens of metres-thick slate, radiolarite and siliceous shale succession (*Hosszúvölgy Basalt*). The original radiometric age of the magmatic rocks is 160–175 Ma and 140 Ma.

The pillow lava and hyaloclastite basalt (*Szarvaskő Basalt*) form an uninterrupted range in the Bükk, between Szarvaskő and the southern margin of the Nagy Plateau. The underlying sedimentary rocks provide evidence of low-grade pyrometamorphism in the contact zone. The thickness of the formation is 300–500m. In the vicinity of Szarvaskő a gabbro intrusion accompanies the basalt; in the latter there is also wehrlite of high ilmenite and titanomagnetite content (*Tardos Gabbro*). Its radiometric age is 165–166 Ma (Dosztály et al. 1998, Pelikán et al. 2005, Pelikán in Főzy ed. 2012).

Deep-marine, foliated clayey siltstone; sandstone, conglomerate (Lökvölgy Fm — 4J)

The lower section of the Jurassic succession of the Bükk Mountains is made up of variegated (lilac, red, green, brown, grey, white) thinly-bedded radiolarite and radiolarian schist (*Bányahegy Radiolarite**, Figure 4, 4Ja). The formation was deposited in a deep marine environment and its thickness ranges between 10 and 30m. The age is Callovian–Tithonian. It is overlain by dark grey clayey siltstone turbidites; these contain thin sandstone beds, and (rarely) conglomerate lenses (*Lökvölgy Fm*, Figure 4, 4Jb). It has been foliated as a result of anchizonal metamorphism ("slate") and it has significant outcrops in the south-western part of the Bükk. The thickness of the formation may exceed 1000m and itsage is Late Dogger – Malm (Dosztály et al. 1998, Pelikán et al. 2005, Pelikán in Főzy et al. 2012).

Deep-marine limestone, foliated siltstone, slate, sandstone, radiolarite, olistostrome (Mónosbél Group — 3J)

The Jurassic succession of the nappes above the Bükk parautochthon comprises black, deep marine clayey siltstone and a sandstone complex (*Mónosbél Group*). The lower section is made up of light grey silicified sandstone (*Vaskapu Sandstone**); within the complex there occur dark grey, thinly bedded radiolarite (*Csipkéstető Radiolarite**), foliated silty claystone, cherty and ooidic limestone (*Bükkzsérc Limestone**) intercalations, as well as olistolith bodies. It has a deep-

water turbidite facies. As a consequence of anchizone regional metamorphism, the formation is highly folded and foliated. Its thickness may exceed 1000m and its age is Late Dogger – Malm (Dosztály et al. 1998, Pelikán et al. 2005, Pelikán in Főzy et al. 2012).

Open-marine nodular, crinoidal limestone, marl (2J)

The Middle–Upper Jurassic succession of the Transdanubian Mountains is made up of pelagic basinal limestone and radiolarite (Császár ed. 1996, Császár 1998, Vörös 1998, Főzy ed. 2012). The lower section of the succession consists of well-bedded, thinly-bedded, dominantly porous light radiolarite with chert nodules, chert lenses and chert bands, as well as chert and siliceous cherty limestone (*Lókút Radiolarite**, Figure 2, 2Ja). The thickness of the formation is several tens of metres; the age is Bathian–Oxfordian. The formation is overlain by red, clayey–nodular, locally cherty limestone ("ammonitico rosso"), the lower section of which also contains limestone breccia (*Pálihálás Limestone**, Figure 2, 2Jb). Its thickness is around 10m. and the age of the formation is Late Kimmeridgian–Early Tithonian. It is overlain by thin-bedded, thin-layered, white or light red *Calpionellidae*-bearing limestone, and cherty limestone. The rock also contains ammonites, belemnites and brachiopod fossil fragments (*Szentivánhegy Limestone**, Figure 2, 2Jc). The thickness of the formation ranges between 5 and 15 m; in places it may also exceed 20m. The age of the formation is Upper Tithonian – Valanginian. A partially heteropic formation of this limestone is the characteristic Upper Jurassic – Lower Cretaceous "biancone" facies of the South Bakony: this is represented by greyish white, lamellar–bedded chert-lens-bearing limestone, clayey limestone and calcareous marl (*Mogyorósdomb Limestone**). The maximum thickness of the formation is 300m and its age is Tithonian–Hauterivian.

The Middle–Upper Jurassic succession of the Mecsek consists of pelagic basinal carbonates with a maximum thickness of 100m; the superficial extent of the carbonatic rocks is restricted to the Kisújbánya Basin (Figure 2, 2Je). The lower section of the succession is made up of red and greenish grey marl (with limestone nodules), calcareous marl and nodular limestone (*Óbánya Limestone**). The thickness of the formation ranges between 10 and 15m and its age is Bathian. The formation is overlain by red and greenish grey, thinly-bedded, lamellar marl, clay marl and siliceous calcareous marl, followed by red, thinly-bedded/laminated siliceous limestone and radiolarite (*Fonyászó Limestone**). The thickness of the formation ranges between 35 and 45m. The formation is assigned to the Callovian–Oxfordian. The upper section of the succession is represented by grey, red or lilac, bedded, nodular, cherty limestone (*Kisújbánya Limestone**). The thickness of the formation is 30–50m. It is assigned to the Kimmeridgian – Middle Tithonian. The uppermost section of the succession is made up of yellowish white limestone that extends over to the Lower Cretaceous. In its lower section it is bedded, while in its upper section it has lamellar parting. It contains chert intercalations (*Márévár Limestone**). The thickness of the formation may exceed 100m and its age is Late Tithonian–Early Hauterivian (Némedi Varga 1998, Nagy I. et al. in Főzy ed. 2012).

The Jurassic succession of the Villány Mountains is not continuous, and it is made up of basinal limestone. The lower section of the succession in the Eastern part of the mountain consists of calc-cemented sandstone and, upward, crinoidal and pebbly limestone and conglomerate (*Somssichhegy Limestone**, Figure 2, 2Jf). Its maximum thickness is 15m and its age is Pliensbachian. It is overlain by grey, ammonite-bearing limestone, the lower horizon of which is characterised by iron ooids and pisoids, while the upper horizon is characterised by stromatolite and several cm-large oncoids (*Villány Limestone**, Figure 1, 2Jg). The rock has been formed on a pelagic submarine plateau and it has a thickness of several metres; its age is Callovian. The youngest member of the Jurassic of the Villány is made up of white or light grey, thick-bedded, micro-oncoidic, ooidic, bioclastic limestone (*Szársomlyó Limestone**, Figure 2, 2Jh). The pelagic submarine plateau facies passes upwards into a shallow marine facies. The formation has a general presence in the Villány Mountains; its thickness ranges between 150 and 300m and its age is Oxfordian–Tithonian (Némedi Varga 1998, Vörös, Török in Főzy ed. 2012).

JURASSIC (UNDIVIDED)

Open-marine limestone, marl, radiolarite (combined non-continuous Jurassic, Transdanubian Range — 1J)

The Jurassic rocks of the Trasndanubian Range are depicted as ones which are present primarily on those areas where hiatuses occur. An example of this is the Middle–Upper Jurassic succession that crops out in the Pilis and which consists of ammonitico rosso (*Tölgyhát Limestone — 6J*) and radiolarite (*Lókút Radiolarite — 2J*). The Jurassic successions (including those which are continuous and those which are not) of the Gerecse also belong to this category. The several tens of metres-wide cracks of the Dachstein Limestone and the Main Dolomite in the SW part of the Vértes are filled with red, massive, fine-crystalline limestone (*Csókakő Limestone**). The age of the formation is Middle Jurassic (Budai et al. 2008).

Crystalline limestone, calc-phyllite, metaconglomerate, greenschist, metatuffite (Felsőcsatár Greenschist, Velem Calc-Phyllite — JK)

The upper part of the metamorphic complex making up the Kőszeg Mountains consists of folded, foliated calc-phyllite and, in several horizons, metaconglomerate intercalations (*Velem Calc-Phyllite*). The original sediment was probably Middle Jurassic – Lower Cretaceous shallow marine marl and delta debris. The thickness of the formation ranges between 200 and 500m. In the southern part of the mountains, as well as in a southwards direction (on the Vas Hill), the outcropping greenschist and serpentinite were formed during the Late Cretaceous; this is a result of the metamorphism of submarine basic lava rocks (*Felsőcsatár Greenschist*). The thickness of the formation is around 100m (LELKES FELVÁRI 1998, IVANCSICS in FŐZY ed. 2012).

CRETACEOUS

LOWER CRETACEOUS

Subvolcanic–submarine volcanic alkaline basalt, trachybasalt, tephrite, phonolite (Mecsekjánosi Basalt — 10K)

The Lower Cretaceous succession of the Mecsek consists of a subvolcanic and submarine volcanic complex (Figure 6); this is composed of alkali basalt, trachybasalt, tephrite and phonolite. The formation crops out on the area of the East Mecsek Syncline and the Northern Sliver. It also formed dykes which were injected into different formations in other parts of the mountains, and itsthickness is several hundreds of metres. Its age is Berriasian–Hauterivian (BILIK in CSÁSZÁR ed. 1996, CSÁSZÁR 1998b).

Deep-marine limestone, marl, conglomerate, sandstone (Apátvarasd Limestone, Hidasivölgy Marl, Magyaregregy Conglomerate — 9K)

The Lower Cretaceous marine succession of the Mecsek — on the margin of the Kisújbánya Basin — is made up of bathyal sediments of diverse grain size (Figure6); these sediments were deposited on the volcanic slopes and are result of the the denudation of basalt volcanoes (BILIK, CSÁSZÁR in CSÁSZÁR ed. 1996, CSÁSZÁR 1998b). Within the conglomerate and sandstone complex, shallow marine (rudists, corals etc.) and pelagic fossils have accumulated in lenses (*Magyaregregy Conglomerate,* Figure 6, 9Ka). The maximumthickness of the formation is around 100m and its age is Valanginian–Barremian. The fine-grained facies of the succession is made up of grey, frequently bentonitic, ammonite-bearing claymarl and marl, with calcareous marl and limestone intercalations and redeposited hyaloclastites (*Hidasivölgy Marl,* Figure 6, 9Ka). The thickness of the formation is several tens of metres and its age is Valanginian–Hauterivian. In the southern foreland of the East Mecsek, crinoidal limestone makes up the Lower Cretaceous succession; its superficial extent is small and itcontains claymarl-calcareous marl intercalations (*Apátvarasd Limestone*). Its maximum thickness is ca. 100m and its age is Valanginian– Barremian.

Open-marine marl, sandstone (Bersek Marl, Lábatlan Sandstone — 8K)

In the north-eastern part of the Transdanubian Mountains (Figure 2), i.e. in the Gerecse, the Lower Cretaceous clastic marine succession covers a large area (CSÁSZÁR 1996, CSÁSZÁR 1998a). Its lower section is made up of grey or lilac red marl and siltstone, accompanied by turbiditic sandstone intercalations. At the base, limestone breccia occurs (*Bersek Marl,* Figure 2, 8Ka*)*. The formation was formed in a pelagic basin. Its thickness is around 100m and its age is Berriasian– Hauterivian.

The Bersek Marl is overlain by greyish green and lilac red medium- and coarse-grained sandstone and pebbly sandstone (turbidite facies) (*Lábatlan Sandstone,* Figure 2, 8Kb). Frequently occurring, there are also marl, matrix-supported conglomerate and limestone intercalations. In the upper section there are chert breccia–conglomerate beds, with limestone blocks containing shallow marine fauna. The facies is a bathyal submarine slope fan. Its thickness may attain 400m and its age is Late Hauterivian–Early Albian.

Shallow-marine biogene limestone (Zirc, Tata, Nagyharsány Limestone — 7K)

The lower section of the Lower Cretaceous, shallow marine carbonate succession of the Transdanubian Mountains is represented by thinly-bedded or lamellar, grey–greenish grey crinoidal limestone (Figure 2); locally, this is accompanied by calcareous sandstone intercalations (*Tata Limestone,* Figure 2, 7Ka). It has a sublittoral facies. Superficial occurrences are

known in the Bakony (from Sümeg to Olaszfalu), as well as in the SW and NE margin of the Vértes. Its maximum thickness exceeds 200m. and its age is Late Aptian – Early Albian.

The upper section of the succession is made up of bedded, biogene platform limestone, containing rudist and other thick-shelled bivalves, gastropods and large foraminifera (Orbitolina) in rock-forming quantities (*Zirc Limestone, Figure 2, 7Kb*). The largest outcrops are in the North Bakony (Zirc Basin), while to a smaller extent it also occurs in the South Bakony and in the south-western part of the Vértes. Its thickness ranges between 25 and 250m and its age is Late Albian (KNAUER et al. in CSÁSZÁR ed. 1996, CSÁSZÁR 1998a).

The Lower Cretaceous shallow marine carbonate platform facies of the Villány Mountains (Figure 6) is made up of grey limestone (*Nagyharsány Limestone*). The several tens of metres-thick lower section is black and, locally, Lofer cyclic brecciated limestone. The bulk of the limestone is thick-bedded or massive; rudist shells and large foraminifera are present in rock-forming quantities (Orbitolinas). Its maximum thickness may attain 400m and itsage is Valanginian–Albian (CSÁSZÁR 1993, 1998b).

<div align="center">LOWER–UPPER CRETACEOUS</div>

Fluvial–paludal clay, sandstone; open marine marl (Tés Clay Marl, Pénzeskút Marl — 6K)

The middle section of the Lower Cretaceous succession of the Transdanubian Mountains (Figure 2) is made up of cyclic, variegated and grey clay, clay marl and marl, accompanied by limestone and sandstone intercalations (*Tés Clay Marl,* Figure 2, 6Ka). The facies is fluvial, lacustrine, marshy and marine lagoonal. The formation crops out in the North Bakony. Its thickness ranges between 60 and 120m and its age is Middle–Late Albian.

The uppermost section of the Lower Cretaceous succession of the Transdanubian Mountains (extending to the lower part of the Upper Cretaceous) is represented by hemipelagic marl (*Pénzeskút Marl,* Figure 2, 6Kb). The lower third of the formation is dolomitic (and also glauconitic) and contains limestone nodules; the upper third is made up of siltstone and sandstone. In the North Bakony it can be found on the surface. Its maximum thickness is around 480m and its age is Late Albian–Cenomanian (CSÁSZÁR 1993, 1998a).

<div align="center">UPPER CRETACEOUS</div>

Subvolcanic microgabbro, basalt, carbonatite (Budakeszi Picrite — 5K)

This formation comprises magmatic rocks that crop out in the quarry of Budaliget in the Buda Hills, and in the quarry of Pákozd in the Velence Mountains. They are highly weathered, dyke-forming alkali basic, ultrabasic subvolcanic rocks. They are partly made up of monchiquite, camptonite, sannaite, alnoite (KUBOVICS, SZABÓ 1988), partly of beforsite, picrite, and spessartite dyke rocks. Their colour is greenish grey, dark grey. The texture is porphyric-panidiomorphic within the dyke, while on the margins it is vitroporphyric and trachytic, in which light green or red olivine (or its carbonate, serpentinite or perhaps green mica pseudomorphs), pyroxene (augite, Ti-augite) phenocrysts, and black mica (phlogopite, and along the edge of the dykes, biotite) can be recognised by the naked eye. The matrix is made up of feldspar (sanidine and orthoclase, bound to carbonatic nodules) and — as a general accessory constituent — opaque mineral; apatite is also present, which occurs exclusively in the middle of the dykes. In the matrix there are acicular mica, sanidine, analcime and, here and there, carbonatic or silicate crystal nodules made up of opaque minerals.

The dyke of the Velence Mountains is a dolomitic carbonatite, with 47–51% carbonate content (from olivine). Its composition is beforsite (HORVÁTH et al. 1983) and the age of the formation is 77.3–69 Ma (K-Ar method).

Fluvial clay, siltstone; sand–sandstone, gravel (Csehbánya Fm — 4K)

The lower section of the Upper Cretaceous succession of the Bakony is made up of variegated or greenish grey clay, clay marl, siltstone, and sand, sandstone and gravel (Figure 2). It is fluvial, floodplain sediment. Its thickness increases from west to east; the average thickness is 50m, but in the vicinity of Csehbánya it exceeds 200m. Its age is Santonian–Early Campanian (JOCHÁNÉ EDELÉNYI in CSÁSZÁR ed. 1996, HAAS 1998a).

Shallow-marine, rudistid limestone (Ugod Limestone — 3K)

The Upper Cretaceous shallow marine platform carbonate facies of the Bakony is represented by light grey, thick-bedded rudistid limestone (or limestone with shell fragments of rudists)(Figure 2). Its extent is restricted to two parallel NE–SW-trending ranges: between Sümeg and Ajka, as well as around Ugod. The thickness of the formation ranges between 100 and 300m, and its age is Campanian – Early Maastrichtian (HAAS 1998a, HAAS in CSÁSZÁR ed. 1996).

Open-marine marl (Polány, Jákó Marl — 2K)

The lower section of the Upper Cretaceous pelagic basinal facies of the Bakony is represented by grey clay marl, marl, and calcareous marl (Figure 2); in the lower section solitary corals and molluscs can be found, while in the upper section there are thick-shelled bivalves (*Jákó Marl*). On the surface, it occurs in the North Bakony (Bakonyjákó, Ugod), as well as in certain parts of the South Bakony (Ajka, Sümeg). Its maximum thickness is 100m and its age is Campanian. The formation is overlain by well-bedded, grey clayey limestone, calcareous marl, and marl; in the upper section there is silty marl (*Polány Marl*). The maximum thickness of the formation is 800m and its age is Late Campanian (HAAS 1998a, HAAS in CSÁSZÁR ed. 1996).

Deep-marine conglomerate, sandstone; marl (Nekézseny Conglomerate — 1K)

The Upper Cretaceous succession of the Uppony Mountains is made up of thick-bedded conglomerate, accompanied by intercalating sandstone and marl beds (Figure 3). Locally, rudistid limestone blocks are also present inside it. It is a submarine slope sediment, formed as a result of gravitational movements ("gosau conglomerate"). Its thickness is several hundreds of metres and its age is Santonian (?)–Campanian (HAAS 1998b, PELIKÁN et al. 2005).

EOCENE

Bauxite, bauxitic clay (Gánt Bauxite — 6E)

This formation consists of pelitomorphic intraclastic bauxite, bauxitic clay, kaolinic clay and, locally, it is accompanied by extra and intraclastic lenses, as well as redeposited bauxite debris. These features occur in piedmont sediments and karstic dolines. They originate from the weathering of the Mesozoic carbonates and the redeposition of older bauxites (MINDSZENTY et al. 2000). The maximum thickness of the formation is 60m. Its age cannot be determined from the fossil record, but the fission track data of the zircon minerals indicate a SW to NE-shifting Ypresian–Priabonian age. (Thus it is somewhat older than the overlying sediments).

Paralic, limnic brown coal, clay, freshwater limestone, calcareous marl (Dorog, Kosd Fm — 5E)

In its role as the starting member of the Middle Eocene transgression cycle, this succession is deposited on the Palaeo–Mesozoic basement or the Gánt Bauxite Formation. Its consists of terrestrial piedmont, fluvial, lacustrine, marshy–boggy and paralic sediments, which were deposited in a brackish water environment. There are, however, intercalations, which indicate that there were normal salinity conditions. The succession is mostly covered. Its lower part is made up of fluvial, lacustrine clay, sand, and breccias originating from the gravel beds or from the denudation of the nearby Mesozoic formations; furthermore, proluvial and deluvial debris is present, alongside redeposited bauxite (lower part of the *Dorog Fm,* Figure 7, 5Ea) and, possibly, also conglomerate (which originated from the denudation of magmatic rocks), and tuffaceous, clayey and bauxitic rocks (*Kosd Fm,* Figure 7, 5Eb). The upper part of the succession is characterised by lacustrine and brackish, as well as paralic coal-bearing beds and coal seams; in the latter marine intercalations (which formed in normal salinity water) also occur (BÉRCZI, JÁMBOR eds 1998). On the basis of the fossils of the intercalating beds and those of the overlying sediments, the age of the succession is Middle and Upper Eocene. It crops out in the south-eastern foreland of the Vértes (above the Gánt Bauxite), in small patches in the northern part of the Gerecse, in the Buda Hills, and in the area of Dunabalparti-rögök (Left Side Blocks of the Danube). It also occurs on the surface in the southern foreland of the Bükk, with a thickness of 10–90m.

Shallow-marine mollusc-bearing marl, silt, sandstone (Csernye Fm, Csolnok Clay Marl — 4E)

The shallow marine and deep neritic formations of the Middle Eocene transgression cycle show a continuous transition from the overlying sediments of the coal-bearing Dorog Formation. In the 10 to 20m (max. 50 m-thick), shallow marine marl and calcareous marl, siltstone and sandstone beds fossil gastropods, bivalves and corals also occur; this indicates eutrophic conditions. Frequently, the fossils have accumulated in a lumachelle-like manner (*Csernye Fm,* Figure 7, 4Ea). The formation gradually passes upwards into a homogenous, deep neritic, well-bedded, grey clay marl and marl succession, the lower third section of which is frequently glauconitic. This formation is related to the high-water horizon of the transgression cycle (*Csolnok Clay Marl,* Figure 7, 4Eb). Characteristic fossils include small-sized large foraminifera (which had a low light requirement); locally, these can be found in large amounts. Examples include *Operculina*, small *Nummulites* — primarily *N. subplanulatus, Assilina*, orthophragminas and there are also thin-shelled molluscs and typical *Pteropodas*
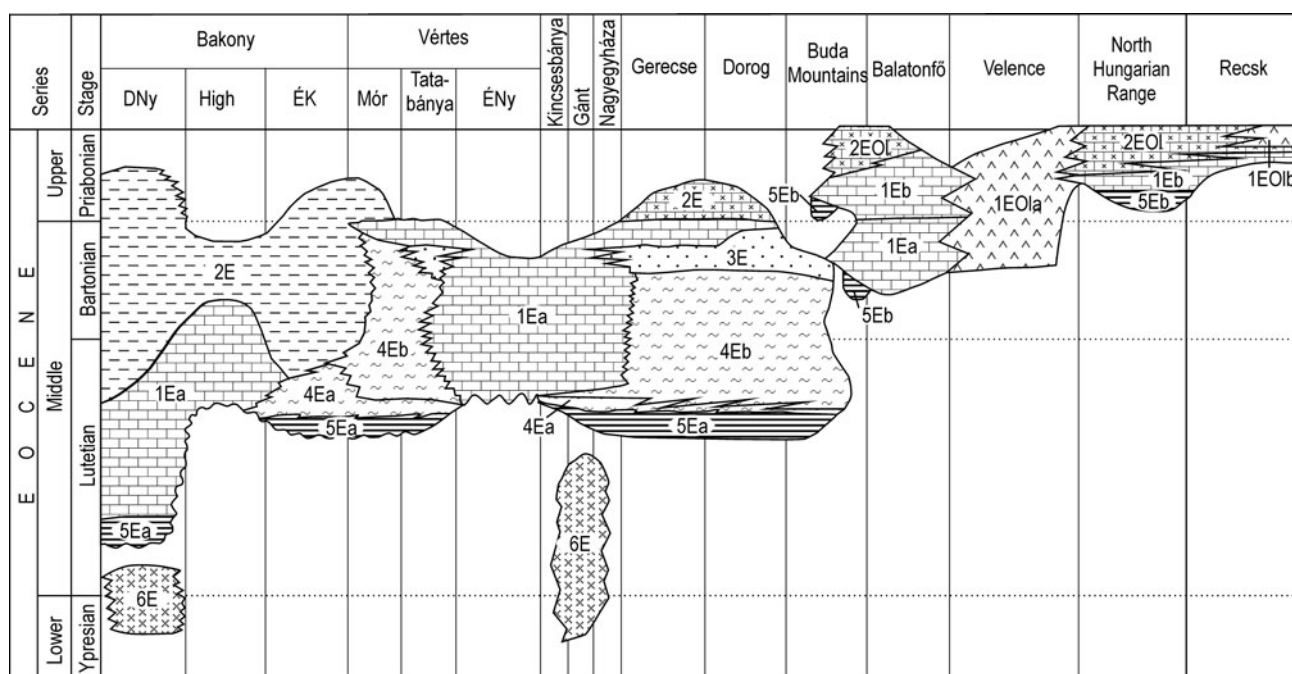
Figure 7. Eocene and Eocene–Oligocene lithostratigraphy (based GYALOG, BUDAI eds 2004, reworked)

Legend: 6E – Gánt Bauxite, 5Ea – Dorog Fm, 5Eb – Kosd Fm, 4Ea – Csernye Fm, 4Eb – Csolnok Claymarl, 3E – Tokod Fm, 2E – Padrag Marl, 1Ea – Szőc Limestone, 1Eb – Szépvölgy Limestone, 2EOl – Buda Marl, 1EOla – Nadap Andezite, 1EOlb – Recsk Andesite

(KECSKEMÉTINÉ 1963, 1966). The foraminifera indicate oligo- and mesotrophic conditions. The thickness of the formation ranges between 20 and 120m. The Csolnok Clay Marl generally occurs in the area of the Transdanubian Mountains. Its heteropic facies is the shallow marine Szőc Limestone, which represents the substratum of the marl. The marl, however, overreaches the extent of the limestone. The upper part of the formation contains sandy intercalations in the north-eastern part of the Transdanubian Mountains, indicating interfingering with the Tokod Formation. At other places, the Szőc Limestone interfingers with thicker, shallow marine facies. The overlying rock of the formation is known only in the north-western part of the Transdanubian Mountains, where the deep-marine Padrag Marl is deposited on the limestone. Its age is Upper Lutetian – Lower Bartonian. The formation crops out on the marginal parts of the Vértes and the Gerecse (in smaller patches), in the south-western part of the Vértes, and in the northern part of the Gerecse (with a larger areal extent).

Shallow-marine marl, sand, sandstone (Tokod Fm — 3E)

The formation is dominantly made up of sand and, subordinately, clayey, siltstone and clay marl beds. Locally, it has developed from the deeper marine Csolnok Formation without transition, and with submarine erosional horizons. These horizons were previously considered to be erosional unconformities (KERCSMÁR 2005). Locally, the coarser-grained siliciclastic sediments come only after the silty, fine sandy beds, which are deposited in the Csolnok Formation. In the most complete successions these are thin sand layers of upward-increasing thickness and grain size. The sandstone contains plant fragments but no fossil fauna. Locally, the sand-intercalation–bearing clay marl beds are overlain by coarse-grained sandstone; this exclusively contains *Nummulites perforatus* and thick-shelled, frequently bio-perforated mollusc shells (*Strombus, Ampullina, Ostrea, Crassatella)* (KECSKEMÉTINÉ 1966, KERCSMÁR 2010) ("perforatus horizon"). The *Nummulites perforatus* beds are overlain by beds with *Nummulites striatus* and an excessively rich mollusc assemblage ("striatus horizon"). The upper third of the succession comprises extremely complex and diverse fine sandy, silty, clayey beds; in the vicinity of Csolnok it is accompanied by brown coal lenses (Lencsehegy beds). In the northern part of the Gerecse, the formation is underlain by the Csolnok Formation; this contains siliciclastic intercalations which are interpreted as pro-delta turbidites. In the south-western part, however, the formation is underlain by the carbonatic sediments of the lower part of the Szőc Limestone, which is a heteropic facies of the Csolnok Formation. The formation is overlain by carbonatic successions, which have developed from the siliciclastic beds and extend to the lower part of the Priabonian (Szőc Limestone) (KERCSMÁR 2005, BUDAI, FODOR eds 2008). The thickness of the formation is 10–20m in the south-western part of the Gerecse, while in the north-east it ranges between 150 and 250m. The siliciclastic beds of the formation have diverse facies. They occur only in the north-eastern part of the Transdanubian Mountains, in the Gerecse, between the Dorog Basin and the Tatabánya Basin. The formation crops out in the north-eastern and south-western part of the Gerecse, as well as on the south-western margin of the Dorog Basin.

Open-marine silty marl (Padrag Marl — 2E)

The lower part of the formation consists of plankton, foraminifera-bearing (*Globigerina* sp.) basinal marl ("globigerina marl"), accompanied by thin andesite tuff intercalations. The grey, greenish grey formation contains thin-shelled neritic mollusc fossils (*Nuculana, Ringicula, Cylichna, Dentalium*), deep marine pteropods (*Prachyalocyclis* sp.), deep marine ostracods (*Agrenocythere* sp.) and several *Nautilus* species. The upper part of the formation comprises coarse-sandy marl and calcareous, clayey sandstone beds of submarine canons and fans, with a large amount of volcanic grains; the latter have accumulated due to gravitational movements. Beside the oceanic nannoplankton, the formation also contains many redeposited shallow marine fossils which originated from the outer shelf (*Discocyclina* sp., *Nummulites* sp., *Operculina* sp., *Marginella* sp., *Natica* sp., *Cerithium* sp., *Tubulostium* sp., *Musculus* sp.) (BÁLDINÉ BEKE, BÁLDI 1990, SZTANÓ, FODOR 1997). The Padrag Marl developed gradually from the glauconite-rich Csolnok Clay Marl, which was deposited in an upper slope environment on the shelf margin. The total thickness of the formation ranges between 100 and 300m and its age is Bartonian – Lower Priabonian. There are superficial occurrences in the north-eastern and south-western part of the Bakony and in the north-western part of the Gerecse.

Shallow-marine biogene limestone, calcareous marl (Szőc, Szépvölgy Limestone — 1E)

This carbonate succession was formed in a shallow marine (ramp and slope facies) environment, and it is dominantly made up of yellowish grey limestone, clayey limestone, sandy limestone and calcareous marl. It contains fossils indicating normal salinity: primarily large foraminifera, locally red algae in rock-forming quantities, as well as molluscs, echinoids, decapods, corals and the remains of vertebrata.. The formation stretches over the area of the Transdanubian Mountains and the North Hungarian Mountains, in the form of a carbonatic succession that gets younger from SW to NE. With regard to its extent and age, it can be divided into two well-separable parts. In the area of the Transdanubian Mountains the Early Lutetian – Early Priabonian *Szőc Limestone* (so-called "Main Nummulites Limestone") extends up to the Buda Line (Figure 7, 1Ea). The formation is mostly present in the north-western part of the mountain range, but also occurs in smaller patches in the south-eastern forelands. It overlies Mezosoic rocks, the Csernye Formation, and in the northern part of the Gerecse, the siliciclastic Tokod Formation. The latter pinches into the formation, thus separating it into two parts in the south-western foreland of the Gerecse (KERCSMÁR 2005, 2010). In accordance with the transgressional succession, the formation is overlain by the heteropic Csolnok Formation.

The Priabonian *Szépvölgy Limestone* shows a continuous transition from the Szőc Limestone in the Velence Mountains. It contains thin andesite tuff intercalations (GYALOG, HORVÁTH eds 2004). Along the Buda Line and along the southern margin of the Bükk, it overlies the Mesozoic carbonates or the clastic succession of the Kosd Formation (Figure 7, 5Eb). South-eastwards, over a short distance, the formation passes into the deep-marine basinal Buda Marl (2EOl) which, on the margins, overlies it with a short temporal transition. As a result of the structural development related to the Eocene basin evolution, the carbonatic sediments formed on the margin of the ramp (and which were accumulated on the upper part of the sedimentary slope) may have undergone plastic deformations with gravitational movements of high density or in the forms of olistoliths the sediments may have been redeposited into heteropic basinal facies (Csolnok Clay Marl, Buda Marl) (FODOR et al. 1992, FODOR et al. 1994, KERCSMÁR, FODOR 2005). Biostratigraphic division of the limestone beds is ensured by the large number of *Nummulites* species (KOPEK et al. 1964; KECSKEMÉTI 1980, 1993) and the zone indicator forms of the *Orthophragminas* (LESS 1987). The Middle Eocene Szőc Limestone is 20–200 m-thick, while the thickness of the Upper Eocene Szépvölgy Limestone varies between 30 and 40m.

EOCENE–OLIGOCENE

Open-marine marl (Buda Marl — 2EOl)

This light grey, greenish grey (on weathered parts, light brown, yellowish brown), hard, highly silty marl, clayey siltstone is accompanied by bentonitic and tuffite intercalations of some centimetres or (rarely), a half metre thickness. It contains plankton foraminifera and thin-shelled *Propeamussium* forms. It is a pelagic siliciclastic succession which was deposited in water of up to 200 m-depth. It has a rapid transition from the heteropic coastal Szépvölgy Limestone, represented by a maximum 20 m-thick bioclastic, calcarenitic limestone and calcareous marl succession; the latter contains many remains of *Bryozoa* ("Bryozoan marl"). The carbonate content decreases upwards. In some horizons the formation also contains semi-consolidated limestone olistoliths and allodapic limestone bedsoriginating from the shallow shelf. It can be distinguished from the overlying Tard Clay by the high calc-content and by the general absence of lamellar bedding (as a result of bioturbation). Its formation began in the Priabonian, as indicated by the *Isthmolithus recurvus* nannoplankton (NP20

biozone) described from the lower part of the formation. The age is also justified by the *Nummulites fabianii* redeposited from the shallow shelf. On the area of the Buda Hills, close to the Priabonian-Kiscell boundary, the formation gradually passes upwards into the Tard Clay. According to the *Globigerina tapuriensis* plankton foraminifera, its formation in the north-eastern region extends to the Lower Oligocene. In the Buda Hills it occurs south-east of the Buda Line facies boundary, while in the North Hungarian Mountains it is present only sporadically and is represented by thin beds (BÁLDI 1983, 1998; FODOR et al. 1994).

Andesite (stratovolcanic, subvolcanic), pyroclastic rocks, metasomatite
(Nadap, Recsk Andesite — 1EOl)

The *Nadap Andesite* (1EOla) constitutes the Zala–Balaton–Velence andesite arc that occurs along the Balaton Line. The Balaton Line belongs to the northern part of the Mid-Hungarian structural zone, which represents the south-eastern tectonic boundary of the Palaeogene Basin of Hungary. The lava rocks and pyroclastic subvolcanic formations of the multi-phase stratovolcanic activity crop out in the eastern part of the Velence Mountains. The rocks include biotite-amphibolite andesite, –agglomerate, –tuff, pyroxene andesite, dacite and diorite intrusions, as well as contact metamorphic and hydrothermal metasomatic formations (BÉRCZI, JÁMBOR eds 1998). The calc-alkalic lava rocks related to the subduction are dominantly made up of andesite and basaltic andesite; however, rocks of a basalt, dacite and trachyandesite composition are also present. The magma, penetrating the Palaeozoic shales, the Carboniferous granites and the Upper Permian – Lower Triassic carbonatic sediments form volcanic necks, dykes and intrusive breccias (BENEDEK 2002). According to the fossils of the intercalating beds, the age of the formation is Middle and Upper Eocene (Figure 7). The K-Ar age (29–42 Ma), however, indicates Middle Eocene – Early Oligocene volcanic activity (GYALOG, HORVÁTH eds 2004). The thickness of the formation exceeds 1000m.

In the north-eastern continuation of the structural zone of the Balaton Line (in the surroundings of Recsk), the *Recsk Andesite* (1EOlb) crops out; this is related to the Darnó Zone. The formation is made up of calc-alkalic, subvolcanic rocks and andesite stratovolcanic forms; it also contains terrestrial and submarine lava and pyroclastic rocks, as well as intrusive and metasomatized rock bodies. The composition of the intrusions and subvolcanic bodies is diorite porphyry, quartzdiorite-porphyre and instrusive breccias; the volcanics are made up of porphyric amphibole–biotite andesite, –agglomerate, and amphibole–pyroxene andesite. The metasomatites consist of propylitizated, skarn, jarosite-bearing, kaolinic and sericitic rocks (BÉRCZI, JÁMBOR 1998, BENEDEK 2002). The Recsk Andesite is underlain by the 5 m-thick Buda Marl (NP21 zone), deposited on the Priabonian Szépvölgy Limestone. The andesite is overlain by a clayey formation containing nannoplankton association of the NP24 zone and Oligocene large foraminifera (*Lepidocyclina* sp., *Nummulites kecskemetii*, *Operculina complanata*) (LESS et al. 2008). According to the fossil record of the underlying and overlying formations, the age of the volcanic formation is Late Priabonian – Late Kiscellian (Figure 7, 8). The thickness of the formation exceeds 800m.
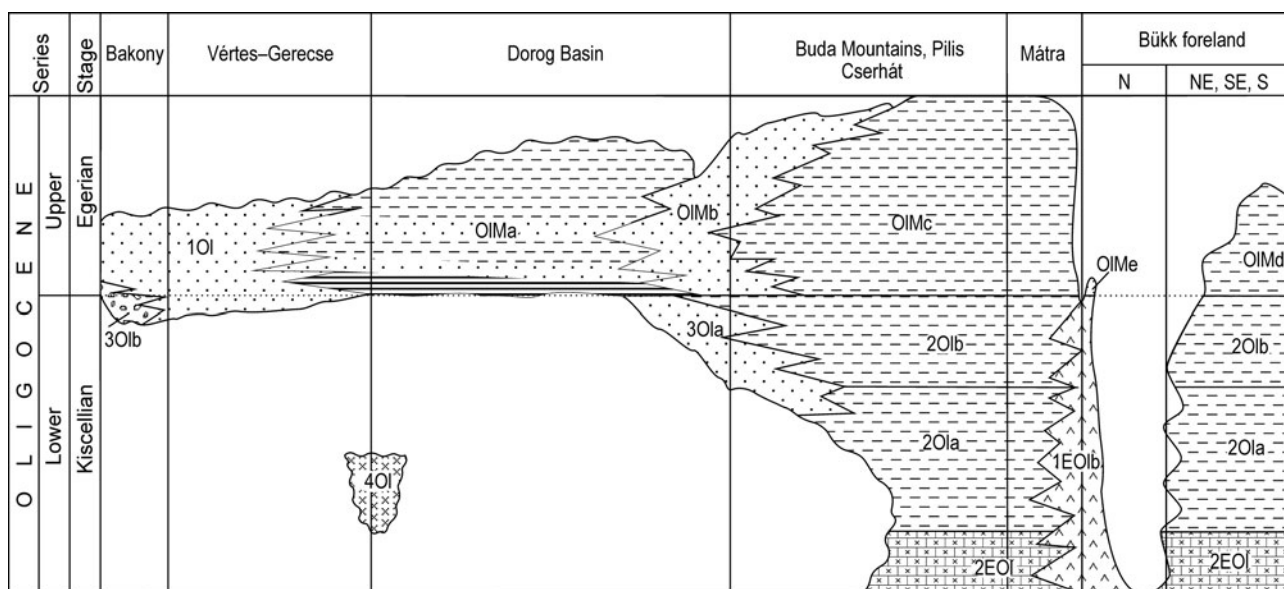
OLIGOCENE

Redeposited bauxite, clay (Óbarok Bauxite — 4Ol)

West of the Buda Line (BÁLDI, NAGYMAROSY 1976, FODOR et al. 1992), as a result of the Oligocene uplift and the following denudation ("infra–Oligocene denudation", TELEGDY ROTH 1927), the bauxite was redeposited and trapped in the depressions of the karstified basement. The bauxite is pelitomorphic and is also made up of bauxite clasts; it contains pebbles and carbonised plant fragments. The youngest underlying rock of the formation is Eocene limestone, while the oldest is represented by the Mány or Csatka Formations. The thickness of the bauxite is a maximum of 20–30m; the average thickness is 1–2m. It occurs in the north-eastern part of the Transdanubian Mountains but it can be detected in the north-eastern part of the Bakony as well.

Shoreline sandstone, conglomerate (Hárshegy Sandstone, Iharkút Fm — 3Ol)

The characteristically basin marginal *Hárshegy Sandstone* (Figure 8, 3Ola) dominantly comprises fine-grained and (locally) coarse-grained sandstone, pebbly sandstone, conglomerate, (locally) caolinic sand and refractory clay, with fine sandy, clayey siltstone intercalations. At its base, isolated patches of red clay or coal-bearing (coal seams) variegated clay occurs. The cement material of the frequently cross-bedded sandstone and the conglomerate in the zone of the Buda Line is hydrothermal silica, chalcedony and limonite, and (rarely) barite, calcite or kaolinite. Its facies is littoral–shallow sublittoral with normal salinity; in the Esztergom-Dorog Basin it is brackish–lagoonal. In places it is fossil-poor, while locally it is

Figure 8. Oligocene and Oligocene-Miocene lithostratigraphy (based GYALOG, BUDAI eds 2004, reworked)

Legend: 2EOl — Buda Marl, 1EOlb — Recsk Andesite, 4Ol — Óbarok Bauxite, 3 Ola — Hárshegy Sandstone, 3Olb — Iharkút Fm, 2Ola — Tard Clay, 2Olb — Kiscell Clay, 1Ol — Csatka Pebbles, OlMa — Mány Fm, OlMb — Törökbálint Sandstone, OlMc — Szécsény Schlier, OlMd — Eger F., OlMe —Csókás Fm

unusually rich in fossils of diverse fauna (BÉRCZI, JÁMBOR eds 1998). The formation is unconformably deposited on older Eocene and Mesozoic formations, with the exception of (i) the area of the Romhány Block, where it shows a continuous transition from the Tard Clay, and (ii) the area of Alcsútdoboz, where it overlies the Tard Clay with uncertain unconformity. The eastern and north-eastern boundary of the formation is represented by the Buda Line, where it interfingers with heteropic basinal Kiscell Clay. It is usually overlain by the Kiscell Clay or, west and south-west of the Buda Line, by Törökbálint Sandstone. On the basis of nannoplankton (NP24 zone), the age of the formation is Upper Kiscellian. However, according to the Romhány section, in several areas its formation possibly began at the end of the NP23 zone, at the beginning of the infra–Oligocene denudation. In most places, however, its formation could possibly be connected to the transgression event which resulted in the formation of the Kiscell Clay (BÁLDI, 1983).

Westwards, its extent is restricted to the area of the Buda Hills, the Pilis and the eastern margin of the Gerecse, as well as the area of the Duna-balparti rögök (Left Side Blocks of the Danube). It was deposited on the infra–Oligocene denudation surface and its thickness does not exceed 200m.

Part of the *Iharkút Formation* (Figure 8, 3Olb) is the same age as the upper part of the Hárshegy Sandstone, while elsewhere it is younger. West of the Hárshegy Sandstone it is a distal, isolated formation bordered by unconformity levels in its lower and upper parts. The terrestrial and coastal fan sediment is dominantly made up of calcareous conglomerate and variegated–mottled clay, in which calcareous sandstone lenses have been deposited. The material of the pebbles and the calcareous sand in the formation are mostly Middle Eocene Szőc Limestone and Eocene bioclasts. The pebble material is mostly that of pebbles from the Csatka Formation. The more clayey beds contain redeposited nannoplankton of the NP19 zone, Oligocene sporomorphs and charophytas. The age of the formation is uncertain; it is probably Early Oligocene, although its formation may have begun in the Priabonian. Its occurrence is restricted to the area of the Northwest Bakony andthe area of Iharkút–Németbánya–Bakonyjákó. Its maximum thickness is around 140m.

Open-marine clay, silt, clay marl (Tard, Kiscell Clay — 2Ol)

The *Tard Clay* (Figure 8, 2Ola) develops continuously from the Buda Marl, parallel with decreasing calc-content. The formation is lamellar (laminitic), poorly bedded clayey siltstone made up of alternating dark grey and light, fine and coarse-grained laminas. The organic-rich formation was deposited in a euxinic, shallow bathyal environment, in 30–300 m-deep water. It shows no sign of bioturbation. Its heteropic coastal facies is Hárshegy Sandstone, deposited along the Buda Line and west of it. Fossils in the formation include poor foraminifera and nannoplankton assemblages, pteropodas, endemic mollusc forms, as well as plant fragments and fish remains. In the non-laminitic part of the formation, allochtonous benthos fauna occurs. On the basis of the ecological demand of the microfauna, the formation can be divided into three easily distinguishable parts. The lower part was formed in a bathyal marine environment; the middle part was formed in a shallow marine environment (with two Spiratella horizons — the so-called "mollusc horizons"); while the upper part was formed in

brackish water, in a rapidly deepening basin (characterised by a lamellar structure and containing a large mass of plant fragments). The formation is 2–80 m-thick; its age is Lower Kiscellian (NP22–23) and it occurs south-east and east of the Buda Line.

The light grey, bioturbated *Kiscell Clay* (Figure 8, 2Olb) consists of fine-grained, clayey siltstone. It is not laminitic. It contains 15–20% carbonate and it shows a continuous transition from the Tard Clay. In the lower member of the succession, graded and non-graded fine-grained sandstone and clayey silty beds have been deposited. In these beds pebbly, sandy fluxoturbidites and glauconitic beds also occur, containing shallow marine mollusc shells (*Chlamys, Ostrea*) originating from the siliciclastic shelf. Around Bükkszék the formation contains several metres-thick weathered tuff intercalations. In the formation there are well-preserved foraminifera and mollusc faunas of high diversity, beside which there are echinoids, Sepia forms and ahermatipic corals. The Kiscell Clay was deposited on a well-oxygenated, 300 to 500 m-deep, open marine, shallow bathyal sea bottom. The thickness of the formation ranges between 10 and 1000m. The formation extends beyond the Buda Line in the west, where it was deposited on the near-coastal Hárshegy Sandstone; in the basin it overlies the Tard Clay while westwards, the Hárshegy Sandstone remains the heteropic facies of the Kiscell Clay. Here the concordant overlying formation of the Kiscell Clay is the Törökbálint Formation, which towards the basin is heteropic with the Csatka Formation. Between the Buda Line and the Darnó Line the formation is continuously overlain by Szécsény Schlier. The Kiscell Clay gets thinner northwards and it is present in the Esztergom Basin, in the area of the Dunazug Mountains; it can also be found on the southern forelands of the Buda Hills, the Pilis, the Vértes and the Gerecse (BÁLDI 1983, BÉRCZI, JÁMBOR eds 1998). According to nannoplankton, the age of the formation is Late Kiscellian (NP24 zone).

Terrestrial–fluvial–lacustrine clay, sand–sandstone, gravel–conglomerate (Csatka Fm — 1Ol)

This is an alluvial, floodplain siltstone and clay formation. The lower part is red and variegated, while in its upper section it is oil green, greyish grey. It is made up of alternating medium- and fine-grained biotitic sandstone and calcareous clay; in this clay collapsed plains, root traces, calcareous nodes and coal bands frequently occur. In the cyclic succession, conglomerate and variegated clay beds and point bar intercalations appear ca. every 15 metres. The grain size of the pebbles of the conglomerate decreases west-to-east. In the rare sandy and pebbly basin sediments *Unio inaequiradiatus* occurs, while in the floodplain, pelites terrestrial and subaeric gastropods, as well as freshwater molluscs are present.In the Northeast Bakony, in the lower part of the Csatka Formation, coal-bearing beds are present, while in the area of Oroszlány, in the upper part of the succession, brackish beds (”cyrena beds”) are deposited with typical mollusc fauna (*Tympanotonus* sp., *Potamides* sp., *Pirenella* sp., *Congeria basteroti, Polymesoda* sp.=*Cyrena* sp.). The formation unconformably overlies the denudation surface of the Mesozoic or Eocene formations. The thickness of the formation increases as the grain size decreases; the increase is from west to east, with the average thickness being 100–300m; however, in the area of Oroszlány and Mór it can attain 800m. Overlying sediments include those of the Miocene and Pleistocene (which are deposited with unconformity). North-eastwards, stretching into the foreland of the Vértes and in the area of the Tatabánya Basin, it interfingers with the coastal, brackish water, upward marine shelf facies Mány Sandstone; eastwards, the latter passes into the Törökbálint Formation (BÉRCZI, JÁMBOR eds, 1998). On the basis of the molluscs and the poor nannoplankton assemblage, the age of the formation is Upper Oligocene, Egerian (NP 24–25). However, the deposition of the formation in the foreland of the Vértes had possibly already begun at the very end of the Kiscellian (BUDAI, FODOR eds 2008). It crops out in the north-western foreland of the Transdanubian Mountains. South-westwards, it can be traced up to the western margin of the Bakony.

OLIGOCENE–MIOCENE

Marine–brackish water–lacustrine clay, claymarl, siltstone, sandstone, conglomerate (Mány Fm, Törökbálint Sandstone, Szécsény Schlier, Eger, Csókás Fm — OlM)

The *Mány Formation* (Figure 8, OlMa) is dominantly made up of alternating calcareous siltstone, clayey siltstone, and cross-bedded sand and sandstone beds; in these beds there are conglomerate and variegated clay intercalations and coal bands. The formation was deposited in brackish water, in a shallow marine lagoon. The formation contains intercalations of sediments formed in freshwater, and sea water of normal salinity. Locally, there are brown coal seams in the lowest third section of the succession. It is either deposited on the Hárshegy Sandstone from which it gradually developed, or it is unconformably deposited on rocks older than Oligocene. The Mány Formation occurs in the north-eastern part of the Transdanubian Mountains. It has superficial occurrences in the western and eastern foreland of the Gerecse and in the Dorog Basin and its thickness varies between 200 and 600m. According to the heteropic Csatka Formation, the development of the Mány Formation probably started at the end of the Kiscellian and continued during the Late Oligocene (KORPÁS 1981,

NAGYMAROSY, GYALOG in GYALOG ed. 1996, NAGYMAROSY, GYALOG in CSÁSZÁR ed. 1997, GYALOG ed. 2005, SELMECZI, FODOR 2008, NAGYMAROSY, GYALOG 2012). The assertion about its "integration" into the Törökbálint Sandstone Formation is not a new idea (SZTANÓ et al. 1998): in 2012 the Oligocene Working Committee of the Hungarian Stratigraphic Commission proposed the re-classification of the Mány Formation as a member of the Törökbálint Formation.

The *Törökbálint Sandstone* (Figure 8, OlMb) was formed in normal sea water, in a shallow sublittoral or locally, sandy-coastal environment. It is composed of sandstone (locally cross-bedded) and sand of diverse grain size. It contains siltstone and clay intercalations ("Pectunculus obovatus sand", "Cyrena beds"). It is found east of the occurrences of the Mány Formation (namely, the Dorog Basin, the Pilis highland and the Buda Hills, the Pest Plain, the left bank of the Danube at the Danube Bend, and the Cserhát Hills). Its thickness varies between 200 and 500m. In the eastern foreland of the Gerecse and in the Dorog Basin it can be distinguished from the Mány Formation only by its faunal record (NAGYMAROSY, GYALOG 2012).

The *Szécsény Schlier* (Figure 8, OlMc) is made up of grey, greenish grey, fine sandy, micaceous clayey siltstone, siltstone and clay marl. In this formation there are fine sandstone intercalations ("Chattian Schlier"). Furthermore, this deep sublittoral-shallow, bathyal open marine formation was formed in sea water of normal salinity. It continuously develops from the Kiscell Clay and at the margin of the Borsod Basin it is underlain by the Bretka Formation. West of the Galgavölgy it interfingers with the Törökbálint Sandstone. It is overlain by the Pétervására Sandstone (with which it interfingers)and the Zagyvapálfalva Formation. It occurs from the Cserhát up to the Western Borsod Basin. The thickness of the formation is 200–700m and its age is Egerian–Eggenburgian (HÁMOR 1985, HÁMOR, NAGYMAROSY in GYALOG 1996, HÁMOR, NAGYMAROSY in CSÁSZÁR 1997, GYALOG ed. 2005, NAGYMAROSY, HÁMOR 2012).

The *Eger Formation* (Figure 8, OlMd) was deposited in a normal sea water–deep sublittoral environment. It is made up of mollusc-bearing silty clay marl with glauconitic, tuffitic sandstone intercalations, pebbly turbidite beds and locally, with lepidocyclina-bearing limestone bed. In its upper section, the formation consists of a regressive succession made up of alternating sandy siltstone–sand–sandstone, which developed in a brackish water–shallow lagoon, and developed continuously from the Kiscell Clay. Its upper contact is erosional. Its thickness usually does not exceed 200m; the maximum thickness is 400m. It occurs around the Bükk Mountains (GYALOG ed. 2005, NAGYMAROSY 2012).

The shallow marine *Csókás Formation* was formed in normal sea water (Figure 8, OlMe). It consists of large foraminifera and red, algae-bearing, glauconitic calcareous marl and calcareous sandstone. In the latter there are also abrasional limestone blocks of variable size (reaching a diameter of up to 1 m). In the Bükk, the formation overlies Triassic rocks, while on the Lahóca Hill at Recsk, it occurs transgressively on the Recsk Andesite. At Recsk, it passes upwards into the upper part of the Kiscell Clay. In the Rudabánya Mountains it is known from boreholes and can also be found in smaller tectonic patches. Where it extends beyond the state border it is known as the Budikovany Limestone Formation. The thickness of the formation reaches a maximum 30m. Its age is Late Kiscellian – Early Egerian (LESS in GYALOG ed. 1996, LESS in CSÁSZÁR ed. 1997, GYALOG ed. 2005, LESS 2012).

MIOCENE

LOWER MIOCENE

Shallow-marine sandstone; sandstone with pebbles, silt (Pétervására Sandstone, Zagyvapálfalva Fm — 31M)

The *Pétervására Sandstone Formation* is made up of grey, greenish grey or yellowish brown glauconitic, biotitic cross-bedded or bedded sandstone of variable grain size (GYALOG ed. 2005), and pebbly sandstone ("glauconitic sandstone"). In the upper horizon there are weathered tuff and bentonite grains. The formation was deposited in sea water of normal salt content. It is usually poor in fossils but well-preserved examples can occasionally be found. It occurs on the area of the Palaeogene Basin of the North Hungarian Region. It crops out at the northern foot of the Mátra and on the hilly lands north of the mountains, between Ipolytarnóc and Ózd. Northwards, it can be followed up to Fülek. Its thickness varies between 150 and 550m (BÁLDI 1983, HÁMOR 1985). According to nannoplankton (NP25, NN1, NN2/3 zones) its age is Late Oligocene – Early Miocene (NAGYMAROSY, BÁLDI-BEKE 1988).

The *Becske Formation** is a cycle-terminating formation in the North Hungarian Mountains; it is made up of brackish and marshy-fluvial facies comprising marine interbeddings. Upwards, it is consists of pelitic sandstone, siltstone with lignite, and fluvial gravel and sand. Its age is Late Oligocene–Early Miocene.

The dominantly terrestrial, fluvial (floodplain, streamline (and, rarely, delta-type) *Zagyvapálfalva Formation* is made up of variegated clay, sand and gravel. It is usually well-bedded, bedded, and thick-bedded. The formation has examples of the preserved footprints and bones of certain mammals (ancient rhino, Proboscideans, birds etc.) in the famous Ipolytarnóc beds. In the delta facies succession there are brackish-water molluscs and driftwoods. The formation overlies (mostly with

a hiatus) the Budafok Sand Formations or older formations (Pétervására Sandstone, Becske Formation*, Szécsény Schlier). Its upper boundary is indicated by the appearance of Gyulakeszi Rhyolite Tuff. It occurs in the North Hungarian Mountains. Its exposures can be followed from the eastern, north-eastern foreland of the Börzsöny up to the Borsod Basin. The thickness of the formation varies between 30 and 60m. It was probably formed in the younger section of the Eggenburgian, possibly in the Ottnangian (HÁMOR 1985, HÁMOR in GYALOG ed. 1996, HÁMOR in CSÁSZÁR ed. 1997, GYALOG ed. 2005).

Fluvial–paludal, shallow-marine clay, silt, sand–sandstone, gravel–conglomerate (Szászvár, Budafok, Felsőnyárád Fm — 30M)

The lower part of the *Szászvár Formation* occurs in South Hungary and is made up of a fluvial–floodplain succession comprising cyclically alternating, variegated (greenish grey, reddish brown, lilac) siltstone, sand, sandstone, gravel and conglomerate (a so-called "terrestrial formation"). This passes upwards into a fluvial–marshy, dominantly grey, greenish grey clay–sand–sandstone succession; in the latter there are also carbonaceous clay and earthy–woody brown coal intercalations (the so-called "limnic formation"). Frequently, one can also encounter molluscs (Unio, Brotia, Theodoxus) and fossils of Sirenia. The upper part of the limnic succession is characterised by yellow, pebbly sand. In the Szászvár Fm there are rhyolite tuff intercalations (namely, the Gyulakeszi Rhyolite Tuff). In the area of the Zala and the Dráva Basins it is known form boreholes. The thickness ranges between 500 and 700m with the maximum thickness being around 1000m. According to the investigations of NAGY L.-né (1969), the age of the formation is Eggenburgian–Ottnangian (HÁMOR 1970, HÁMOR in GYALOG 1996, HÁMOR in CSÁSZÁR 1997, GYALOG ed. 2005).

The *Budafok Fm* is dominantly made up of coarse-grained yellow and grey sandstone, accompanied by pebbly–clayey intercalations. Its facies is a shallow marine, estuary, intertidal plain. It is quite rich in fossils ("large Pecten beds"). It can be observed with decreasing thickness on the right bank of the Danube from Budafok to Érd, and from there, up to Törökbálint. It is also known to occur in the Visegrád Mountains (primarily on their eastern margin, in the area of Dunabogdány–Tahi–Leányfalu) and in the Cserhát Hills. Its thickness is 80–150m and its age is Eggenburgian (BÁLDI 1958, 1983, KORPÁS 1981, HÁMOR 1985, GYALOG ed. 2005).

The *Felsőnyárád Fm* is primarily composed of sandy–pelitic structures, in which there also occur brown coal seams and rhyolite tuff intercalations. It unconformably and transgressively overlies the basement. Its basal formations are composed of the weathered debris of the basement, followed by freshwater pebbly–sandy clay, variegated clay and brown coal; furthermore, in the upper section of the formation, siltstone and sandy siltstone are present; these were formed in brackish water and later, in a shallow sea. In the area of the Darnó Zone the formation has a local occurrence. Its thickness is 100–200m and its age, according to the brackish water and marine fauna record, is Egerian-Eggenburgian (RADÓCZ 1978, HÁMOR in GYALOG ed. 1996, HÁMOR in CSÁSZÁR ed. 1997, GYALOG ed. 2005, RADÓCZ pers.comm.).

Rhyolite–rhyodacite ignimbrite (Gyulakeszi Rhyolite Tuff — 29M)

The formation known as the "lower rhyolite tuff" is made up of greyish white, white, biotitic, pumiceous rhyolite–rhyodacite welded ignimbrite; the bulk of this was consolidated on dry land, while the same took place with a smaller portion in a wet medium. The formation is usually thick-bedded and poorly layered. It frequently contains carbonized plant fragments (leaf, branch and trunk) which are present in large quantities around Ipolytarnóc. The lower boundary of the formation is represented by volcanic rocks which make up the bottom of the ignimbrite succession. The upper boundary is marked by the first sediment bed. The rocks of the formation may have been deposited in the crevice systems of the structural zones, with a hiatus on Palaeozoic–Mesozoic and Paleogene formations and with an apparent concordance into Lower Miocene terrestrial formations. The formation occurs on the surface in the North Hungarian Mountains: namely, in the Salgótarján Basin, in the northern foreland of the Mátra, in the Bükkalja and in the southern foreland of the Bükk. There is also a superficial occurrence in the northern foreland of the Mecsek, where its volcanosediment facies is also known; it was deposited here during fluvial sedimentation (Kisbattyán). It has also been discovered in several boreholes throughout the country and its thickness varies between 30–400m. The radiometric– palaeomagnetic age of the formation was previously considered to be 18.5–21 million years, marking the Ottnangian Stage. However, the rhyolite tuff stripes of the underlying sediments belong to the Eggenburgian Stage (HÁMOR 1998, GYALOG ed. 2005). According to more recent radiometric age measurements (PÁLFY et al. 2007), the deposition of the Gyulakeszi Rhyolite Tuff occurred later, only 17 million years ago (Karpatian Stage).

Coastal sand–sandstone, gravel, breccia, limestone (Bretka, Bántapuszta Fm — 28M)

The *Bretka Fm* is made up of yellowish–greyish white, thick-bedded, coarse and medium-grained, (locally) fine crystalline limestone–conglo breccia (microbreccia and microconglomerate);it is cemented by calcareous material. Locally, in the rock there are fossils and biogene clasts in rock-forming quantities (molluscs, foraminifera). The facies of the

formation is normal marine littoral, shallow sublittoral. It was formed in a well-oxygenated sea (NAGYMAROSY in GYALOG ed.1996, NAGYMAROSY in CSÁSZÁR ed. 1997, GYALOG ed. 2005, SZENTPÉTERY, BÁLDI pers.comm..) On the surface it occurs in the north of Hungary: in the southern side of the Aggtelek Karst and in the Rudabánya Mountains. The thickness of the formation varies between 2 and 30m and based on its fossil record its age is Late Egerian.

The *Bántapuszta Fm* is composed of calcareous, sandy and coarse-grained rock, as well as corallinaceae-bearing limestone and sporadically, pebbly sandstone. The formation is rich in mollusc, foraminifera and bryozoan fauna. It also contains a characteristic nannoplankton assemblage and tuff intercalations. Its facies is littoral (KÓKAY 1972, 1973; KÓKAY pers.comm., Kókay in GYALOG ed. 1996, KÓKAY in CSÁSZÁR ed. 1997), its occurrence is restricted to the area of the deep line of the Várpalota Neogene basin. It crops out at Bántapuszta. In the area of Várpalota–Inota its clayey-sandy facies is also known to occur; however, it is not known for certain whether it is present around Budapest. The average thickness of the formation is 20–60m and its age is Ottnangian.

Brackish water–paludal brown coal, sand–sandstone (Salgótarján, Brennberg Brown Coal — 27M)

The *Salgótarján Brown Coal* is a Lower Miocene formation known to occur in the area of the North Hungarian Mountains. It contains 3–5 brown coal seams which are economically viable. In the Salgótarján Basin, the facies of its basal formation is, locally, a fluvial–delta and plain–marshy facies, with a gravel–coarse sand–variegated clay succession; in this succession the brown coal seam-bearing section has a limnic facies and only the uppermost seam is paralic. The seam-bearing beds are overlain by carbonaceous clay and siltstone, andfish scales and trace fossils can be found. The formation has a mostly paralic facies in the West and East Borsod Basins, and also in the Cserehát Hills. The coal seams can be followed from the Cserehát (Alsóvadász) up to the Borsod Basin bordering the Bükk Mountains in the north and in the west, and also up to the northern part of the Mátra and the southern part of the Nógrád Basin. From here its goes northwards, turns north-west at Salgótarján, and at Nógrádszakál extends further towards the Kékkő Basin in Slovakia. The thickness of the coaly formation varies between 30 and 70m and in the Borsod Basin it even attains 300m. At its western occurrence, in the Salgótarján Basin and partly, in the West Borsod Basin, its formation is restricted exclusively to the Ottnangian. In the eastern region, however, it was formed both in the Ottnangian and in the Karpatian (HÁMOR 1985, HÁMOR in GYALOG ed. 1996, HÁMOR in CSÁSZÁR ed. 1997, GYALOG, BUDAI eds 2004, RADÓCZ, HÁMOR pers.comm..).

The *Brennberg Brown Coal* comprises a travertine–marshy succession which overlies the metamorphic rocks of the Sopron Mountains (1Pz, 2Pz). In it, between the overlying and underlying coal-striped sandy formations, there is a 4–16 m-thick autochtonous brown coal seam. It occurs west of Sopron, at Brennbergbánya and near to the state border. The thickness of the formation is 23–27m. The most probable age is Ottnangian (HÁMOR in GYALOG ed. 1996, HÁMOR in CSÁSZÁR ed. 1997, KISHÁZI, IVANCSICS 1975, IVANCSICS pers.comm.).

Fluvial–coastal gravel–conglomerate, sand (Szuhogy, Darnó Conglomerate, Ligeterdő Gravel — 26M)

The *Szuhogy Fm* is made up of red, reddish brown, coarse-grained conglomerate, cemented with limonitic–calcareous clay and marl. Both the lower and the upper boundary are unconformable horizons. The clasts of the cyclic fan are diverse in size and roundness, and are mainly composed of metamorphic limestone variants; the bulk of the latter are similar to the Palaeozoic limestones of the Uppony and the Szendrő Mountains. The proportion of sandstone, siltstone and slate pebbles is low, while the quantity of the unaltered limestone pebbles is insignificant. The formation is underlain by Abod Limestone, or the black claystone (accompanied by limestone lenses) which underlies the Abod Limestone. The formation is overlain by the Lower Pannonian Edelény Fm, as well as its tuffaceous basal formation and, possibly, the Szécsény Schlier, which can be identified by the glauconite content observable on the base of the overlying sediments. Partly washed-in flora and fauna fragments can be seenin the cement material that lived from the end of the Oligocene. On the surface, the formation is present at the south-eastern boundary of the Rudabánya Mountains, lying north-east of the Szénvölgy-tető (Szénvölgy High) in a 4.5 km-long, maximum 1 km-wide band. The maximum thickness of the formation is 150m. According to the fossil content its formation probably occurred in the Early Miocene (GYALOG ed. 2005).

The *Darnó Conglomerate* is made up of coarse-pebbled conglomerate at the base, fine-pebbled coarse sandstone in the middle section, and coarse-pebbled sand in the upper section. The bulk of the pebbles of the transgressive basal formation are composed of dolomite, radiolarite, basalt, nummulitic limestone and quartzite. It occurs west of Eger, on and around the Darnó Hill. Its thickness exceeds 50m on the Kis Hill of Darnó. In the middle part of the succession there is a ditrupa-bryozoan fossil assemblage in the calcareous sandstone bands; in the coarse-pebbled sand of the upper section there are ostrea beds and *Balanus concavus* remnants. According to the fossil record, the age of the formation is Eggenburgian (GYALOG, BUDAI ed. 2004).

The *Ligeterdő Gravel* is a poorly-sorted sand and gravel formation (”Auwaldschotter”), found in the surroundings of the Sopron Mountains. Pebbles and conglomerate from the crystalline basements can be observed in the lower section, above which there is conglomerate composed of carbonatic and metamorphic pebbles. The succession is overlain by a well-

bedded sand and marl series. The latter was formed in freshwater and brackish water and it contains a few badly preserved molluscs (*Congeria, Unio, Neritina, Melanopsis, Helix* sp.); in several places there are some thin, carboniferous intercalations. At the topmost part of the succession there is coarse-grained gravel and conglomerate. The formation overlies the Brennberg Fm, which overreaches theextent of the former significantly. Over a large area the formation is underlain by a crystalline basement. Its stratigraphical overlying formation is the transgressive Baden Clay. Ligeterdő Gravel also appears on the surface, around the Sopron Mountains. It has also been exposed by many deep boreholes on the Little Plain. Its thickness exceeds 600m and its age is Ottnangian–Karpatian (GYALOG ed. 2005). On the basis of explorations in Austria the formation of the Ligeterdő Gravel possibly extends to the Early Badenian (PASCHER 1991).

Shoreline sand–sandstone, gravel–conglomerate
(Egyházasgerge, Fót, Budafa Fm — 25M)

The shoreline–coastal plain *Egyházasgerge Fm* is made up of cross-bedded, chlamys-bearing sand, sandstone, and gravel (which frequently starts with basal conglomerate).In the West Borsod Basin, at the base of the formation shoreline, a several tens of metres-thick, upward-fining transgressive gravel succession is deposited; this succession contains local limestone and dolomite pebbles, and poor marine fauna. The formation overlies the Salgótarján Brown Coal Fm; the basal beds have a brackish water, estuary facies and contain Congeria and Oncophora (Rzehakia) fossils. The formation passes into a Corbula–Arca-bearing succession (as the Chlamys fossils disappear), and progresses northwards into the West Borsod Basin. This succession interfingers with the Salgótarján Fm in the East Borsod Basin. The main formation is overlain by the Garáb Schlier or the regressive Fót Fm. In the direction of the basin it interfingers with the Garáb Schlier and crops out in the North Hungarian Mountains (Börzsöny, Cserhát, and Borsod Basins). The thickness of the formation varies between 30 and 100m and its age is Karpatian (HÁMOR 1985, GYALOG, BUDAI ed. 2004, GYALOG ed. 2005).

The *Fót Fm* includes a shallow marine, shoreline–coastal, "bryozoan–balanus-bearing" calcareous–coarse-grained succession; in its upper section this succession is characterised by volcanic intercalations. These sediments were deposited in filling-up basins at the end of the Early Miocene. The typical facies is greenish grey, frequently with glauconitic bryozoan–balanus-bearing calcarenite, calcareous pebbly sandstone, sandy limestone, end-cycle-sand (with calcareous concretion), and clay (with gypsum) intercalations. Off-white limestone–calcareous sandstone, sandy small-pebbly limestone, yellowish white sandstone, and small-pebbled calc-cemented sandstone variants are also common. Towards what was oncean open sea, the formation is stratigraphically underlain by the heteropic Garáb Schlier Fm, the Bántapuszta Fm, and the Egyházasgerge Fm in North-east Hungary. Their transition is continuous. In the Transdanubian Region, in the direction of the dry land, the formation passes into the Perbál Fm. Its upper boundary is marked by the appearance of volcanic rocks (Tar Dacite Tuff, Hasznos Andesite) and it crops out in the western part of the North Hungarian Mountains The most beautiful exposures are located in the area of Fót–Csomád, Püspökhatvan–Acsa, and Galgaguta. There are smaller outcrops in the northern foreland of the Mátra and also in the Mecsek. In the Transdanubian Region it occurs in the surroundings of Bántapuszta and Alcsútdoboz. The thickness of the formation varies between 30 and 70m and its age is Karpatian (HÁMOR 1985, HÁMOR in GYALOG ed. 1996).

The *Perbál Fm** is a Karpatian–Badenian terrestrial succession found in the north-eastern part of the Transdanubian Region.

The *Budafa Fm* comprises two formation associations — (i) a shoreline–abrasion coastal, coastal plain, locally delta, yellowish grey, yellow sand, sandstone, gravel and conglomerate succession, which interfingers with (ii) a fish scale-bearing lagoonal clay marl, siltstone, fine-grained sand succession. However, there is also a limnic coastal facies, dominantly made up of limestone, subordinately sand–sandstone (which, locally, contains massive volumes of Congeria). It crops out in the Mecsek. Its thickness varies between 600 and 700m and its age is Karpatian (HÁMOR 1970, HÁMOR in GYALOG ed. 1996, GYALOG ed. 2005).

Andesite (lava, subvolcanic), -pyroclastics, tuffite (Hasznos, Mecsek Andesite — 24M)

The *Hasznos Andesite,* known from the North Hungarian Mountains ("lower andesite"), is dominantly made up of submarine, partly subvolcanic pyroxene andesite agglomerate, tuff and tuffite, and subordinately lava rocks. On the surface, larger patches are found in the northern part of the Mátra. Its thickness ranges between 80 and 200m and its age is Karpatian (HÁMOR 1985, GYALOG ed. 2005).

The *Mecsek Andesite* comprises grey (in weathered form: greenish grey or reddish grey), dominantly amphibole andesite (in the upper part: pyroxene amphibole andesite) lava rocks, subvolcanic bodies and dykes (without pyroclastics). This formation is usually foundoverlying Mesozoic formations (locally, the Szászvár Fm), and is itself overlain by the Gyulakeszi Rhyolite Tuff or Karpatian basal beds (deposited with erosional unconformity). On the surface, it is known from the Komló area ("Komló andesite"). Its thickness is around 300m and its formation occurred 20–21 million years ago, in the Eggenburgian–Ottnangian (HÁMOR 1970, 1998; GYALOG ed. 2005).

Open-marine sand, siltstone, clay, clay marl (Garáb, Tekeres Schlier — 23M)

The North Hungarian *Garáb Schlier* ("Helvetian Schlier") is a grey, cyclically alternating, bioturbed sand, micaceous fine sand, siltstone, clay, clay marl series, with current and washout surfaces and signs of mud transport. It contains rich marine macro- and microfauna and nannoplankton, and locally redeposited tuffite bands can be observed in it. In the eastern part of the East Borsod Basin the formation does not contain any fossils. It develops from the cycle-starter, coastal Egyházasgerge Fm on the Nógrád-type area of the Garáb Schlier. At other places it is unconformably deposited on older formations, and even overreaches their extent. Its stratigraphic overlying formation is the Fót Fm, although volcanic rocks can frequently be found deposited on it. It crops out in the Börzsöny and the Cserhát, in the Salgótarján Basin, in the East Borsod Basin and along the eastern margin of the Cserehát (Hernád Graben). Its average thickness ranges between 200 and 300m, with its maximum thickness being around 800m. The age of the formation is Karpatian (HÁMOR 1985, GYALOG, BUDAI ed. 2004).

The Transdanubian *Tekeres Schlier* is composed of a near-shore, open marine, yellowish grey, grey fine sandy siltstone, sandy clay and clay marl series; this series is rich in marine molluscs, foraminifera and nannoplankton. In the South Transdanubian region it can usually be found continuously overlying different members of the Budafa Sandstone Fm. At other places it is unconformably deposited on older Miocene rocks or the basement. It is often overlain by the shallow marine Lajta Limestone, with which it laterally interfingers. On the area of the deep basins, younger Miocene siliciclastic formations can be found deposited on it (for example, Szilágy Clay Marl), and it is also present in most parts of the Transdanubian region; furthermore, it crops out in the Mecsek area. Its thickness ranges between 200 and 400m, with its maximum thickness exceeding 500m. The age of the formation is Karpatian – Early Badenian, and this is indicated by Badenian fauna and tuff intercalations (HÁMOR 1970, 1998; HÁMOR in GYALOG ed. 1996; HÁMOR in CSÁSZÁR ed. 1997).

Dacite tuff, rhyolite tuff, rhyolite (Tar Dacite Tuff, Gyöngyössolymos Rhyolite — 22M)

The *Tar Dacite Tuff* ("middle rhyolite tuff") comprises greyish white, light grey, biotitic, pumiceous dacite tuff; this was deposited from the volcanic ash cloud which emerged along rejenuvated fault lines. In the Nógrád Basin it is deposited on Lower Miocene marine formations and in the Bükkalja, on the Gyulakeszi Rhyolite Tuff. In the Bükkalja region fiamme-type rocks and welded ignimbrites are also known. The formation also crops out in the North Hungarian Mountains and around Fót. Its average thickness is around 30m, but in the boreholes of the Nyírség it may attain several hundreds of metres. The age of the formation is Karpatian –Early Badenian (GYALOG, BUDAI eds 2004; GYALOG ed. 2005; HÁMOR 1985, 1998; JÁMBOR pers. comm.).

The *Gyöngyössolymos Rhyolite* is made up of lilac–pink, medium-grained, bedded, thick-bedded volcanic rocks and, dominantly, lava rocks; in the latter, subordinately, there are also perlite (Gyöngyössolymos) and spherulitic (Mulató Hill, Lőrinci) sections. The formation overlies the Nagyhársas Andesite with initial tuff. It seems probable that the rhyolite tuff between the lower and middle bed group of the Szurdokpüspök Fm also belongs here. The rhyolite and dacite occurrences of the Mátra can be assigned here as well. The latter are deposited on the middle stratovolcano series and they are older than the "overlying andesite" (Kékes Andesite). The formation crops out in the Mátra and its maximum thickness is 50m. The age of the formation is Badenian (GYALOG, BUDAI eds 2004).

Pyroxene andesite, -pyroclastics; rhyolite and dacite tuff; garnet-bearing amphibole andesite (Nagyhársas, Karancs, Csákánykő Andesite — 21M)

The *Nagyhársas Andesite* makes up the bulk of the Mátra. It is composed of alternating pyroxene andesite lava, agglomerate and tuff ("Mátra middle andesite"), in which, subordinately, there are also acidic (rhyolite, dacite) pyroclastic intercalations. The lava rocks are generally grey, red or green; the colour of the pyroclastics is white, red or green. In addition to the Mátra, the formation occurs in the east of the Cserhát Hills as well. At Gyöngyösoroszi, hydrothermal mineralisation is related to it. The thickness of the formation generally ranges between 500 and 1000m but, locally, it may exceed 2000m. It was formed during the Early Badenian and its K-Ar age is 14.5–16.3 Ma. Its younger radiometric age is possibly due to secondary alteration (GYALOG, BUDAI eds 2004, ZELENKA 2010).

Karancs Andesite is made up of light grey–bluish grey subvolcanic andesite and dacite. A laccolith penetrated into Oligocene – Lower Miocene clayey-sandy sediments. One may find superficial occurrences in the Karancs–Medves region. According to radiometric age measurements (13.5±1 and 14.9±1.6 Ma), it was possibly formed during the Badenian (GYALOG, BUDAI eds 2004).

Csákánykő Andesite ("carbonatic pyroxene andesite") comprises light grey, coarse-grained, carbonatised pyroxene andesite. With regard to its formation, it is partly intrusive and partly extrusive. No pyroclastic rock types are known to

present. Its relation with the surrounding sedimentary rocks along contact zones can be observed in several exposures. In the north-eastern part of the Mátra individual rock bodies can be distinguished, and these are characterised by high carbonate content and pyrrhotine veins. The thickness of the extrusive bodies is less than 200m. The radiometric K-Ar age of the formation is 16.4±1.4 Ma; given this measurement, its formation possibly occurred during the Badenian (Gyalog, Budai eds 2004, Zelenka in Baráz ed. 2010).

Shoreline–fluvial gravel, sandstone, siltstone, marl (Pusztamiske Fm, Nagyoroszi Gravel — 20M)

The *Pusztamiske Fm* was deposited in the shallow marine sedimentary basins of the marginal parts of the Bakony, and along the margins of these basins. It is dominantly made up of coarse- and medium-grained, calc-cemented, grey, greenish grey sandstone. At the base of the formation, coarse-grained abrasive gravel and conglomerate have been deposited, while in its upper section siltstone and marl intercalations are more frequent. Intercalating tuff, tuffite and bentonitic clay layers may also occur. It overlies pre-Badenian formations with erosional and angular unconformity, usually starting with a coarse-grained basal bed. In the West Bakony the pebble material of the formation is of local origin or is derived from the redeposition of the pebbles of the Csatka Fm. In the West Bakony it is either overlain by (i) the partly heteropic Lajta Limestone (either continuously or with a level of local unconformity), or (ii) by younger Badenian, Sarmatian, Pannonian or Quanternary beds with unconformity. In the direction of the basin it passes into the Lower Badenian beds of the Tekeres Schlier Fm. In the Várpalota Basin the formation is underlain by the Fót or the Perbál Fm, and overlain by several metres-thick clay up until the Upper Badenian coal deposit. In the surroundings of Pusztamiske and Kolontár, the coarse-grained basal sediments become sandier and the siliciclastic sediments pass into the Lajta Limestone. In the West Bakony it has singificant occurrences around Devecser–Nyirád, but it also occurs in the vicinity of Csabrendek. Its abrasive, shoreline gravel sediments appear on the surface, mostly in the Ajka–Bakonygyepes and the Kolontár areas. The coarse-grained basal sediments become sandier upwards in the succession around the settlements of Pusztamiske and Kolontár. Here, the siliciclastic sediments pass into the Lajta Limestone. In the West Bakony the formation is significant in the surroundings of Devecser–Nyirád, but it occurs around Csabrendek as well. Its abrasion shoreline gravel sediments are the most extent on the surface in the vicinity of Ajka–Bakonygyepes and Kolontár. The sandy shoreline facies of the formation was formed in sea water of normal salt content and is rich in fossils (molluscs and bentos foraminifera assemblage). The typical exposure of the facies is the Szabó sand pit at Várpalota (Kókay 1987, 1988, 1998; Bence et al. 1990, Selmeczi in Gyalog ed. 1996, Selmeczi in Császár ed. 1997, Gyalog, Budai eds 2004). The average thickness of the formation is 50m, with its maximum thickness being around 200m. Its formation occurred during the Early Badenian (NN5 zone, Lagenidaes–Orbulina foraminifera assemblage).

The facies of the *Nagyoroszi Gravel* is an alluvial fan-type and coastal estuary reef-type. The formation is made up of a gravel-conglomerate succession, embedded into bedded–lamellar, flatly cross-bedded quartz sand. Dominantly, the the pebbles originated from metamorphic rocks, but significant amount of carbonates and silica rocks (radiolarite, chert) are present and, subordinately, there are also granite and palaeovolcanic rocks. The small and medium-grained sand–sandstone is well-bedded, andthe material of the grains is quartz. It is frequently micaceous, withcharacteristic balanus and bryozoan horizons. In the upper part of the succession there appear the volcanic rocks of the Nagyvölgy Dacite Tuff which, upwards, suddenly becomes dominant in the succession. The formation crops out on the eastern margin of the Börzsöny, but in isolated patches it is also present inside the mountains. The formation underlies the Badenian volcanic structure and overlies the Karpatian Egyházasgerge Fm. Its thickness can attain 200m and itsage is Karpatian–Badenian (Gyalog, Budai eds 2004).

Shallow-marine, biogenic limestone; conglomerate (Lajta Limestone — 19M)

This lithologically diverse formation is made up of shallow marine limestone, calcareous alga-bearing limestone (formed in sea water of normal salt content), calcareous mollusc-bearing and bryozoan sandstone, and calcarenite; locally, it is accompanied by marl intercalations. The formation is frequently deposited on Miocene or older rocks and, locally, on volcanic formations as well. In the latter case, conglomerate and gravel occurs at its base. In other cases (for example, in the case of deep-marine Badenian siliciclastic underlying formations) its deposition is concordant. The formation is overlain by younger formations (either continuously or with a hiatus). On the surface, it occurs on the low-lying parts of mountains rising from the basins. It crops out (a) onthe Fertőrákos–Ruszt Hills (b) in the West Bakony (c) in the Tapolca Basin (d) in and around Budapest [Tétény Plateau, Törökbálint, Érd, Diósd and Biatorbágy areas] (e) along the northern margin of the Visegrád Mountains (f) in the southern part and along the western margin of the Börzsöny (g) in the Cserhát and along the western margin of the Mátra, and (h) in the Mecsek. At the margins of the mountains its thickness is several tens of metres, with its maximum thickness being around 100m. The age of the formation is Badenian. According to biostratigraphic examinations and radiometric data it was formed in the Early Badenian ("Lower Lajta Limestone") in the West Bakony, in the Tapolca Basin, in the Visegrád Mountains, in the Börzsöny and in the Mátra; it was formedin the Late Badenian ("Upper

Lajta Limestone") in Balatonakali, around Budapest and at Buják. The Lajta Limestone includes the Pécsszabolcs, the Sámsonháza, the Abony, the Rákos and the Ebes Formations; earlier, these were considered to be separate lithostratigraphic units (Bence et al. 1990; Hámor 1970, 1998; Hámor in Gyalog ed. 1996, Császár ed. 1997).

Brackish-water brown coal, mollusc-bearing marl (Hidas Brown Coal — 18M)

The Hidas Brown Coal comprises clayey, xylithic brown coal seam-bearing rocks (lignite, clayey lignite, huminitic clay) which are situated between the underlying and overlying marine formations. The facies is oscillatory, paralic-brackish water (Hámor 1970). In the Mecsek type-area, the barren beds between the coal deposits are made up of grey, sandy, mollusc-bearing clay marl, Cerithium-bearing clay, claymarl, Hydrobia-bearing marl, micro-bedded silty clay marl (that sporadically contains fish scales), and coaly clay. Locally, one can also encounter diatomaceous clay marl in the formation, alongside tuff and tuffite bands and lenses. In the Mecsek, the formation in the marginal facies is underlain by the Lajta Fm, while in the basinal facies it is underlain by the Baden Fm and the Tekeres Schlier. The deposition is concordant. The upper boundary of the formation is marked by a definite rock material change, as well as the presence of formations of marine origin; the latter are of normal salt content, and are rich in macro- and microfauna. In the basin facies the Hidas Brown Coal is conformably overlain by Szilágy Clay Marl, while in the marginal position it is overlain by Lajta Limestone. It crops out in the Pécsbánya Basin and in the Miocene range of the south-eastern foreland of the Mecsek. The thickness of the formation may attain 100–150m. The average thickness of the coal seams is 4–5m. The Mecsek facies was formed during the Middle Badenian (Hámor 1970, 1998; Hámor in Gyalog ed. 1996; Hámor in Császár ed. 1997). In the surroundings of the Bakony, in the Várpalota Basin and around Berhida the formation of the coal occurred in the Late Badenian. Here, the coal-bearing succession is deposited on older Badenian terrestrial succession. A Congeria–Bulimus-bearing bed is deposited directly on the coal beds, and is covered by alginitic clay marl of freshwater origin. In the succession rhyodacite tuff and tuffite intercalations can be found. The formation is unconformably overlain by the Gyulafirátót Fm. In the surroundings of Herend–Szentgál the substratum of the formation is composed of Early–Middle Miocene terrestrial rocks, while the overlying formation is made up of younger Badenian sediments; these sediments were formed in sea water of normal salinity. The coal seams were formed in the Early Badenian. The coal-bearing formation found in the surroundings of Pusztamiske is deposited on the Lajta Limestone and also on the Pusztamiske Fm, with erosional unconformity. The formation is continuously overlain by Sarmatian sediments (Kozárd Fm). The age of the coal-bearing formation is Late Badenian (Bence et al. 1990).

Open-marine clay, clay marl (Szilágy Clay Marl, Baden Fm — 17M)

The *Szilágy Clay Marl* is made up of thickly or thinly layered grey, greenish grey, mollusc- and foraminifera-bearing clay marl, silty clay, and fine sandy marl ("Turritella–Corbula-bearing clay marl"). In the East Mecsek, the upper part of the formation is characterised by lamellar diatomaceous marl and diatomaceous earth intercalations. Due to the fine-grained siliciclastic lithology, on a macrosopic scale it can hardly be distinguished from the Baden Fm. Its facies is near-shore open marine; the upper part of the succession was deposited in a shallow, undisturbed lagoonal environment, partly surrounded by Lajta Limestone reefs (Hámor 1970, Hámor in Gyalog ed. 1996, Hámor in Császár ed. 1997, Hámor 1998, Hámor pers.comm.). On the Mecsek type- area it is continously deposited on the Hidas Fm; in most cases it is overlain by the lithologically similar Kozárd Fm; it can be distinguished from the latter on the basis of the characteristic Sarmatian brackish water fauna (Hámor 1970). The Szilágy Clay Marl may interfinger with the Lajta Limestone near to the marginal zones. The occurrence of the formation is general in the Late Badenian sedimentary basins. On the Mecsek type-region it is known to crop out in the area of the Bodolyabér syncline and in the southern foreland of the mountains. It also occurs in the Börzsöny (western foreland, the Szokolya Basin, and Magyarkút) and in smaller isolated patches in the Cserhát Hills and in the Tokaj Mountains. The Corbula–Pereira-bearing rocks which crop out in in the surroundings of Herend were at one time sorted into this formation (Bence et al. 1990, Gyalog, Budai eds 2004); however, more recent investigations relate them with the Baden Fm (Nagymarosy, Kókay pers. comm.). The average thickness of the formation is 50–150m, but in the area of the deep basins it may attain several hundreds of metres. According to biostratigraphic investigations its formation occurred in the younger section of the Badenian (Bohn-Havas et al. 1990, Hámor 1998).

The *Baden Fm* is dominantly made up of open marine, basinal, grey and greenish grey clay and clay marl, with rich mollusc and foraminifera fauna (Hámor in Gyalog ed. 1996, Hámor in Császár ed. 1997). Rocks in the area of Hungary belonging to this formation are usually fine-sandy and schlier-type, thus differing from the typical Austrian facies (Baden-Sooss, Rögl et al. 2008). In the Zala–Dráva Basin the Baden Fm is deposited on the Budafa Fm, while in the surroundings of Budapest, it lies on the Perbál Fm. Around Sopron it gradually develops from the Ligeterdő Fm; in the boreholes of the Little Plain it transgrades over the basement with basal conglomerate. In heteropic facies it interfingers with the Lajta Limestone. The formation is overlain by regressive Badenian formations (Lajta Limestone, Pusztamiske Formations) and Badenian volcanic rocks (North Hungarian Mountains), and it crops out in the surroundings of the inselbergs. In the Sopron

Mountains it is known on the surface in several connected patches. The "tuffaceous white marl" facies of the Baden Fm has been recognisedin the Borsod Basin and, (more recently) is considered to be a separate formation (*Borsodbóta Fm*, GYALOG, BUDAI eds 2004). The formations cropping out in the surroundings of the Börzsöny and belonging to the Szilágy Clay Marl are regarded as rocks of the Baden Fm) (according to NAGYMAROSY, KÓKAY pers.comm.). The thickness of the formation is 50–200m in the mountainous areas, while in deeper basins it may exceed 500m. According to biostratigraphic data, the typical Baden Clay was formed during the Early Badenian (M5 and M6 planktonic foraminifera zones; Lagenidae benthic foraminifera zones; and NN5 nannoplankton zones; RÖGL 1998, NAGYMAROSY 1985, BOHN-HAVAS et al. 1987). Its facies around Budapest was formed during the Middle Badenian (KÓKAY 1990).

The *Borsodbóta Fm** is primarily made up of Early Badenian marine siltstone, tuffaceous sandy siltstone ("tuffaceous white marl") and sand; at the base of this formation there are terrestrial and freshwater gravel–sand–siltstone beds with (locally) travertine lenses.

Welded rhyolite tuff; rhyolite, perlitic rhyolite (Sátoraljaújhely Rhyolite Tuff — 16M)

This formation consists of acidic pyroclastic rocks (ignimbrite, zeolitic ignimbrite, lapilli–tuff, redeposited tuff–tuffite), accompanied locally by rhyolitic lava rocks (rhyolite perlite, rhyolite intrusion, rhyolitic lava sheet). The SiO_2 content of these rocks ranges between 75.3% and 77.8%. Beside the above-mentioned rock types, there also occur rhyodacite tuffs and rhyodacite rocks, with an SiO_2 content of 67–70%. The formation crops out in the surroundings of Sátoraljaújhely. Its thickness is 100–300m and the age of the formation is Late Badenian (GYALOG, BUDAI eds 2004).

Dacite–pyroclastic rocks; subvolcanic dacite, andesite (Nagyvölgy, Holdvilágárok Dacite Tuff, Vágáshuta Dacite — 15M)

The *Nagyvölgy Dacite Tuff* occurring in the Börzsöny Mountains consists of two bed groups. The transitional sedimentary–volcanic bed group is made up of volcanic, volcanic–sedimentary and sedimentary rocks, witha closely even ratio. Characteristic elements of the rocks are volcanic ash and crystalline tuff (which fell into the existing water environment), pyroclastic flows (ignimbrite) and epiclastic accumulations (lahar). The grain size of the volcanoclastic rocks ranges between several mm and several m. The composition of the lava rocks and the subvolcanic bodies is biotite–amphibole–pyroxene dacite, and biotite–amphibole–pyroxene andesite. The clayey sediments are characterised by a poor fossil record. The Nagyvölgy Dacite Tuff crops out in the central part of the Börzsöny and at its eastern margin. Its thickness is 250–600m and the K-Ar age is 15.2–14.8 Ma (KORPÁS ed. 1998, GYALOG, BUDAI eds 2004).

The material of the *Holdvilágárok Dacite Tuff* of the Visegrád Mountains is initially andesite, and later dacite pyroclastic rock (dominantly tuff), with a low amount of shallow marine sediments. It was formed during four volcanic phases. In the Holdvilág Graben the volcanic succession is 70 m-thick, and the K-Ar age is ca. 16.5 Ma (BENDŐ 2001). In the central part of the Visegrád Mountains, and at its eastern margin, subvolcanic biotitic–amphibole andesite is present; at the southern and eastern margin (for example Csódi Hill) subvolcanic and extrusive biotite dacite bodies occur (GYALOG, BUDAI eds 2004).

Vágáshuta Dacite is dominantly made up of subvolcanic pyroxene–amphibole dacite and amphibole dacite (known also in lava and pyroclastic forms); the SiO_2 content of the latter is 63–64%. It crops out in the Tokaj Mountains, where its thickness exceeds 220m. It is known from boreholes in the area of the Nyírség. Here, its thickness is close to 700m. The radiometric age of the latter formation is 13 ± 0.6 Ma (GYALOG, BUDAI eds 2004).

Andesite, -pyroclastics, andesite dyke (Kékes, Magasbörzsöny, Dobogókő Andesite — 14M)

Kékes Andesite comprises dark grey, black, usually compacted pyroxene andesite. The amount of the pyroclastic rocks (tuff, agglomerate) is subordinate; the formation consists mainly of lava rocks. In the Mátra, the so-called "overlying andesite" is mostly deposited on the eroded surface of the Nagyhársas Andesite and, locally, on rhyolite. In the north-eastern part of the Mátra it is underlain by Tar Dacite Tuff. The andesite dykes of the northern foreland of the Cserhát and the Mátra also belong to the Kékes Andesite. The formation crops out in the Mátra and the Cserhát, while in the Nyírség it is exposed by borehole drillings. Its maximal thickness is 200m. It was once considered to be formed in the Badenian but, according to more recent radiometric data, its formation could haveoccurred in the Sarmatian (VARGA et al. 1975, GYALOG, BUDAI eds 2004).

Magasbörzsöny Andesite consists of the lava rocks of the terrestrial lava flows of the palaeovolcanic cone of the High Börzsöny; the pyroclastic breccias are made upof the pyroclastic flows. Volcanic sedimentary and sedimentary rocks are completely absent. The matrix of the volcanoclastics is scoriaceous pyroxene-amphibole andesite; the material of the embedded clasts is pyroxene-amphibole andesite or amphibole-pyroxene andesite. The size of the clasts ranges between several cm and several m. The thickness of the rocks of the lava flows is 10–100m and the extent of the formation is restricted to the Börzsöny. The maximum thickness of the succession is 500m and its age is (on the basis of radiometric and palaeomagnetic measurements) 14.8–14.5 Ma (BALLA 1978, GYALOG, BUDAI eds 2004).

In *Dobogókő Andesite* the dominant components are coarse-grained pyroclastic rocks. However, there are no lava beds and no volcanic–sedimentary orsedimentary rocks. The material of the pyroclastic breccias — formed by pyroclastic flows — is mostly amphibole-pyroxene andesite. The size of the clasts in the scoriaceous andesite sand matrix can attain 1m. The formation crops out in the Visegrád Mountains and its maximum thickness is 500m. The age of the formation (according to radiometric and palaeomagnetic measurements) is 14.8–14.5 Ma (GYALOG, BUDAI eds 2004).

Shallow-marine clay–clay marl (Kozárd Fm — 13M)

The succession is made up of well-bedded (bedded, thick-bedded, banded–laminitic), dominantly grey, greenish grey [mollusc-bearing (Abra-Cardium and Hydrobia-Cerithium)] clay marl and clay. Frequently, fine sandy siltstone, calcareous marl, sandy marl, calcareous sandstone, sandy limestone and tuffaceous clay intercalations occur. In the one time shoreline lagoons, micro-bedded bentonitic, diatomaceous, and alginitic formations were deposited. The shallow marine, open marine, dominantly brackish formation locally contains coal-banded clay and clayey brown coal beds It is usually rich in fossils (primarily molluscs and foraminifera) (*Abra, Ervilia, Mohrensternia, Mactra, Musculus, Cerithium* etc.). In the area of the Middle Eocene sedimentary basins, usually it conformably overlies the Badenian substratum (Szilágy Clay Marl); furthermore, it is (rarely) unconformably deposited on formations older than Sarmatian and overreaches their extent. Locally, it gradually develops from the Sarmatian carbonate sediments (Tinnye Fm) which it may laterally interfinger with towards the basin margins. Depending on the palaeogeographical position, in open marine facies the formation is overlain by an Upper Miocene (Pannonian) succession. The formation is known to occur on the surface in the North Hungarian Mountains and in the Mecsek. In the Tokaj Mountains diatomaceous tuffite and diatomaceous earth beds have also developed. The thickness of the formation ranges between 100 and 500m and its the age is Sarmatian. The lower boundary is represented by characteristic Sarmatian brackish-water macro and microfauna, while the upper boundary is marked by the appearance of the Pannonian inland-sea fauna (*Limnocardium, Congeria, Melanopsis*) (HÁMOR 1985, HÁMOR in GYALOG ed. 1996, HÁMOR in CSÁSZÁR ed. 1997, HÁMOR 1998).

Shallow-marine–brackish-water porous limestone, sand, gravel (Tinnye Fm — 12M)

This formation is made up of (i) shallow marine, near-shore, yellow, yellowish grey, greyish white, biogenic, locally ooidic limestone, (ii) calcareous sandstone, (iii) calcareous mud, (iv) calcareous mollusc-bearing sand, and (v) sandstone ("Sarmatian porous limestone", "Cerithium-bearing limestone"). In the formation, subordinately, there are greenish brown clay and green, calcareous clay intercalations as well. The ooidic limestone variants indicate that there was constant water movement. The cores of the ooids are usually foraminifera. According to recent environmental analogies, a part of the formation was deposited in hypersaline conditions (HÁMOR, IVANCSICS in GYALOG ed. 1996, HÁMOR, IVANCSICS in CSÁSZÁR ed. 1997, HÁMOR 1998). The formation continously develops from the overlying Badenian formations (mostly the Lajta Limestone) or from older Sarmatian formations. The lower boundary of the formation can be assigned to where the Sarmatian brackish water fauna assemblages appear. Overstepping the margins, it is unconformably deposited on older (for example, in the surroundings of Mány, Oligocene, Triassic) formations. The transgressive beds of the formation which overlie pre-Cenozoic rocks contain basal gravel. The formation is either continuously overlain by younger Sarmatian formations or by Pannonian sediments. The upper boundary of the formation is marked by the disappearance of the Sarmatian fauna. Towards the inner part of the basin it laterally interfingers with the Kozárd Fm, from which it can be distinguished by its higher carbonate content (≥50%). It is generally present on the margins of the Middle Miocene sedimentary basins and at the margin of the extension area of the Kozárd Fm. Significant surface occurrences are found (i) in the Mány–Zsámbék Basin in the Transdanubian Mountains (ii) in the surroundings of Sóskút, Biatorbágy and Törökbálint (iii) in the area of the Tétény Plateau (iv) around Nyirád in the Bakony (v) in the Tapolca Basin, and (vi) in the surroundings of Zánka on the Balaton Highland. On the Pest side of the capital, it crops out in Kőbánya. In the Mecsek, it occurs on the surface in the surroundings of Pécsvárad and Pécs. In the Sopron Mountains the formation has three facies: calc-cemented abrasive basal conglomerate, shoreline limestone and calcareous sand, anddelta gravel, conglomerate and limestone. The thickness of the formation ranges between 20 and 170m. Due to its characteristic macrofauna assemblage (*Irus, Ervilia, Cardium, Mohrensternia, Rissoa, Hydrobia* etc.) it is barely distinguishable from the Kozárd Fm (which was formed in deeper water). The age of the formation is Sarmatian.

Terrestrial–fluvial–shallow marine clay, silt, sand, gravel (Sajóvölgy, Gyulafirátót Fm — 11M)

The *Sajóvölgy Fm* which occurs in the North Hungarian Mountains is dominantly made up of (i) alternating proluvial terrigenous debris and fluvial (floodplain, streamline), fluvial-delta, rocks of lacustrine-marshy facies (ii)lacustrine sediments (iii) volcanomict gravel (iv) sand (v) clayey siltstone (vi) diatomite and (vii) limnoopalite. In certain places freshwater mollusc-bearing beds occur as well. Locally in the succession tuff horizons also appear; these are identical with the Badenian–Sarmatian, Sarmatian as well as Early Pannonian rhyolite tuffs. In the Borsod Basin, Sarmatian andesite

volcanism divides the formation into two. The terrestrial formations are deposited on older Miocene rocks or on the direct Badenian stratigraphical substratum (with erosional unconformity). They are overlain by Lower Pannonian formations that gradually pass upward into the Edelény Variegated Clay. In the East Borsod Basin, in the middle and upper section of the formation, there are lignite seams. Larger occurrences existing the Nógrád and in the Borsod Basins, as well as in the area of the Bükkalja and the Cserehát. The thickness of the formation ranges between 20 and 150m; with itsmaximum thickness being 300m (Nyékládháza). According to the tuff horizons of the succession, its formation lasted from the Badenian until the Early Pannonian (HÁMOR 1985, GYALOG, BUDAI eds 2004).

The *Gyulafirátót Fm,* known from the Transdanubian Mountains, is made up of: terrestrial-fluvial, subordinately delta greenish grey or variegated clay with carbonate nodules; bentonitic clay (with calc concretions); siltstone; sandy siltstone; sandstone; gravel; and conglomerate. As a result of brackish water-type ingressions, locally bentonite, diatomaceous earth, subordinately brown coal and gypsum intercalations occur as well. The bentonitized tuff intercalations can be related to the Sarmatian rhyolite tuff explosion. The material of the clasts primarily originates from the denudation of the Bakony area; this area emerged as a result of crust movements at the Badenian–Sarmatian boundary. Furthermore, as a consequence, the basal formations are deposited on diverse Palaeozoic and Mesozoic (in the surroundings of Csór), Triassic (Gyulafirátót, Kádárta and Öskü), Eocene and Oligocene (Guttamási, Fehérvárcsurgó) successions, as well as on the eroded surface of the Upper Badenian alginite succession (Hidas Fm). The formation is overlain by Sarmatian, Pannonian or Quaternary beds Its thickness does not usually exceed 100m and a thicker occurrence is known only in the Várpalota Basin, in the surroundings of Inota. It occurs from the western margin of the Bakony up to the foreland of the Vértes, and crops out around Gyulafirátót and Várpalota (Öskü), and in the surroundings of Polgárdi. Since it interfingers with Sarmatian (based on fossils) marine facies of decreased salt content, its age can be assumed to be Sarmatian (BENCE et al. 1990, BENCE, SELMECZI in GYALOG ed. 1996, BENCE, SELMECZI in CSÁSZÁR ed. 1997).

Red clay, bauxitic clay (Vöröstó Fm — 10M)

The terrestrial rocks which belong here are those that were formed as a result of the resedimentation of the uncovered and thus unprotected bauxites of the Bakony and the Balaton Highland (bauxitic clay, clayey bauxite, red clay, and bauxite pebbles with, locally, high iron content) ("Miocene bauxite"). They are overlain by Neogene formations and even Quaternary sediments. Important superficial occurrences are located in the area of the Nagyvázsony Basin (the Taliándörögd–Kapolcs–Vigántpetend–Nagyvázsony–Vöröstó–Barnag–Tótvázsony area), and in the northern outskirts of Vörösberény (Szentkirályszabadja). On the northern and north-eastern margins of the Tapolca Basin it is primarly known from borehole drillings. It occurs at its greatest thickness in the Nagyvázsony Basin, where it exceeds 70m. According to overlying sediments of the formation in the western part of the Balaton Highland and the Bakony, it is of Badenian–Sarmatian age. However, on the basis of to data from the Isztimér–Bakonykúti–Guttamási area, it is Badenian–Pannonian (GYALOG, BUDAI eds 2004, TÓTH, SELMECZI pers. comm., TÓTH pers.comm.).

Post-volcanic–lacustrine and volcanic formations (limnoquartzite, bentonite, kaolinite, diatomite, clay); rhyolite tuff (Erdőbénye, Szurdokpüspöki Fm — 9M)

In the North Hungarian Mountains the rocks which formed as a result of the volcanism that occurred in the Mátra and the Tokaj Mountains make up two formations. Lacustrine diatomaceous earth, limnoquartzite and geyserite rocks of the Tokaj Mountains (related to the Middle–Late Miocene postvolcanic thermal water activity) belong to the *Erdőbénye Fm;* in the latter, locally, there are clay and sand beds, as well as redeposited rhyolite tuff-tuffite bands; locally, these bands have been highly affected by argillization (bentonite, kaoline). The thickness of the limnoquartzite is several cm (bands) to several m (extent cover). The extent of the geyserite cone is, horizontally, less than it is vertically. The formation frequently contains the remains of plant fragments and, more rarely, terrestrial gastropod fauna. The thickness of the formation ranges between 10 and 70m (GYALOG, BUDAI eds 2004) and its age is Late Sarmatian–Early Pannonian.

In the Mátra, rocks accumulated in the isolated basins in the surroundings of volcanoes which emerged from the sea during the Badenian belong to the *Szurdokpüspöki Fm.* On the basin margins a diatoma-rich lithofacies (diatomite) was formed, while in the deeper, central part of the basins sandy clay, clay and clay marl accumulated. There are also rhyolite tuff, tuffite and limnoquartzite intercalations in the succession. The formation is characteristically tripartite: at the bottom there is a freshwater–brackish water facies, in the middle it is part marine, while upsection a brackish water facies follows again. In the middlemarine succession there are limestone beds that are identical with the Lajta Limestone Fm. From the silica-rich thermal water of the post-volcanic activity and in the surrounding lakes, geyserite and limnoquartzite were precipitated. Typical superficial occurrences are the Prédikáló-tető (Prédikáló High) of Gyöngyöspata and the Köves-hegy (Köves Hill) of Gyöngyöstarján. The Szurdokpüspöki Fm is underlain by Nagyhársas Andesite. The largest superficial occurrence of the formation is the diatomaceous earth mine at Szurdokpüspöki. Its thickness exceeds 200m; according to palaeontological investigation, its age is Badenian (GYALOG ed. 2005).

Pyroxene andesite, dacite; pyroclastite (Amadévár, Baskó, Dubicsány Andesite — 8M)

Amadévár Andesite is made up of grey, dark (greenish) grey, lamellar, bedded, lava bed-like, and acidic pyroxene andesite (60–61% SiO_2). It primarily covers the higher peaks of the north-western part of the Tokaj Mountains (eg. the Nagy-Amadé Hill at Gönc) in the form of a cap or a sheet. Once they were probably part of an uninterrupted lava flow. The dominantly subvolcanic or lava-related pyroxene dacite and, more rarely, pyroxene–amphibole dacite or amphibole-(biotite) dacite, are present to a significant extent at the southern part of the Tokaj Mountains. They originate from magmas related to the same chamber but affected by a different type of evolution. Subordinately, pyroclasts are present as well (agglomerate, tuff). The SiO_2 content is ca. 63%. Amadévár Andesite also crops out in the Nyírség, on the Nagy Hill at Tarpa. The typical thickness of the formation is 70–200m and its radiometric age is 10.3–10.5 Ma (GYALOG, BUDAI eds 2004).

Baskó Andesite is the main terrain-forming stratovolcanic–subvolcanic formation of the Tokaj Mountains; it is made up of acidic pyroxene andesite, amphibolic pyroxene andesite (59–62% SiO_2) and, subordinately, their pyroclastics. Mineralisation-accompanied pseudotrachyte, kalitrachyte, kalimetasomatite etc. variants of the formation primarily occur in the surroundings of Telkibánya. As a result of the differentiation of the andesite lava, more acidic pyroxene dacite, amphibole-pyroxene dacite subvolcanic rocks, and welded ignimbrites were formed. The subvolcanic, (subordinately) lava-type pyroxene andesite — which is more basic compared to the bulk of the formation — is related to multiple separated eruption centres. The pyroclastic rocks (tuff, agglomerate) are of mixed composition (rhyolite+andesite) and are located on the margins of the intermediate volcanic formations or under them. The thickness of Baskó Andesite is several hundreds of metres and its radiometric age is 11.4–12.6 Ma (GYALOG, BUDAI eds 2004).

Dubicsány Andesite is made up of andesite-agglomerate, tuff and tuffite and, more rarely, lava-origin pyroxene andesite (lava breccias and dykes). Locally, the tuff and tuffite succession is partly rhyolitic. In the andesite-pyroclastic rocks there are exotic rock bodies, inclusions (Palaeozoic slate, Oligocene–Miocene sandstone etc.), clay, sand, gravel, as well as acidic tuff and tuffite intercalations. Stratigraphically,t Dubicsány Andesite is deposited in the middle part of the Sajóvölgy Fm. It can be found in the East Borsod Basin and in the northern part of the West Borsod Basin. The thickness of the formation ranges between 10 and 50m. In the tuff and tuffite beds there are plant fragments indicating a Sarmatian age. Given its stratigraphical position, its formation probably started during the Late Badenian, though it is mostly of Sarmatian age (GYALOG, BUDAI eds 2004).

MIDDLE–UPPER MIOCENE

Rhyolite, dacite, tuff, tuffite, agglomerate (Cserehát, Vizsoly, Harsány, Felnémet, Galgavölgy, Szerencs Rhyolite Tuff — 7M)

Cserehát Rhyolite Tuff is made up of scattered rhyodacite tuff beds, comprising rhyodacite crystalline tuff, pumice-rich tuff, fine-grained tuff and tuffite, as well as bentonite. Locally, accretionary lappilis are frequent. The extent of the formation is restricted to the East Borsod Basin and the Cserehát. The formation is underlain by the Sajóvölgy Fm. Eastwards, is can be foundrelated to the Vizsoly Rhyolite Tuff. The radiometric age of the formation is 9–10 Ma (GYALOG ed. 2005).

Vizsoly Ryolite Tuff consists of rhyolite ignimbrite, fallen and redeposited rhyolite tuff, and tuffite. Its upper part is identical with the Cserehát Rhyolite Tuff with which it interfingers. Besides the pyroclastic rocks, rhyolite foamy lava, pumiceous rhyolite and perlite variants are also known; these cover the tuffaceous formations in the form of a cap. The formation crops out in the Tokaj Mountains and in the Nyírség as well. Its maximum thickness is 150m and its the radiometric age is ca. 11 Ma (GYALOG, BUDAI eds 2004).

Harsány Rhyolite Tuff is known from Bükkalja and comprises predominantly fallen ignimbrite, phreatomagmatic, and redeposited rhyolite tuff and tuffite; in the latter, subordinately, dacite and andesite tuffite intercalations occur as well. The formation includes all the dominantly acidic pyroclastic rocks that are found above the Tar Dacite Tuff in the Bükkalja and in its foreland. With the absence of Tar Dacite Tuff, the formation is deposited on Gyulakeszi Rhyolite Tuff Fm. It is overlain by Edelény Variegated Clay. Its thickness does not exceed 140m at the marginal parts of the mountains, but towards the Great Plain the thickness increases. The radiometric age is 14.6–13.5 Ma. It was mostly deposited on dry land (GYALOG, BUDAI eds 2004).

Felnémet Rhyolite Tuff comprises diverse redeposited rhyolite tuff, but fallen and welded, ignimbrite rhyolite tuff bodies are also known in the succession. The rhyolite tuff alternates mostly with sediments. It includes Badenian–Sarmatian acidic pyroclastic rocks, found in the western foreland of the Bükk and on the hilly region between the Mátra and the Bükk. Frequently, along the margin of the Bükk, it is deposited on the basement, while in the central part of the basin it interfingers with Badenian and Sarmatian sediments. Its formation occurred from the Early Badenian until the end of the Sarmatian (GYALOG, BUDAI eds 2004).

Galgavölgy Rhyolite Tuff ("upper rhyolite tuff") comprises grey, biotitic, pumiceous rhyolite tuff and bentonite; it formed as a result of weathering processes. On what was and is dry land, it is represented by ignimbrite and, locally, tuff-breccia (SCHMID 1981, FISCHER, SCMINCKE 1984) (tuff agglomerate in HÁMOR 1985, GYALOG ed. 2005). In the East and West Borsod Basins the formation is deposited on the Sajóvölgy Fm. It occurs across the whole of the countryand it crops out in the North Hungarian Mountains. Its maximum thickness is 30m. The age of the formation is Sarmatian, although the K-Ar, Ar-Ar ages show a large variability (13.7±0.8 Ma) (HÁMOR 1985, GYALOG ed. 2005).

Szerencs Rhyolite Tuff comprises acidic pyroclastic rocks and it only occurs in the Tokaj Mountains. It is in some respectsidentical with Galgavölgy Rhyolite Tuff. Its thickness can attain 350–500m in the Tokaj Mountains and in the Nyírség. The age of the formation is Lower Sarmatian; according to the radiometric ages measured in rhyolites, its formation occurred 11.7–12.3 million years ago (GYALOG, BUDAI eds 2004).

Fluvial–paludal clay, silt; lignite, sand (Edelény Variegated Clay, Hernádvölgy Clay — 6M)

Edelény Variegated Clay is delta plain (fluvial, lacustrine, marshy), grey and variegated clay, clayey siltstone, organic-rich clay, coaly clay, andlignite; near to the base, there are alternating pumiceous sand and pebbly sand beds Upwards, travertine and calcareous marl can be found. Larger uninterrupted patches of the formation can be found on the surface between the Sajó and the Hernád. The thickness of the formation is 50–300m and it was formed during the Early Pannonian (JÁMBOR in GYALOG ed. 1996, GYALOG ed. 2005).

Hernádvölgy Clay is a terrestrial, limnic–fluvial formation, the bulk of which is made up of clay containing carbonate nodules; furthermore, siltstone and sand intercalations also occur. Locally, mollusc and ostracod fauna, and *Chara* oogoniums are present. The formation occurs in the Hernád Valley (between Abaújszántó and Abaújvár). Its age is Late Sarmatian – Early Pannonian (GYALOG, BUDAI eds 2004, GYALOG ed. 2005).

UPPER MIOCENE

The compilation of the geological map of Hungary ended in 2013, when the map was published in print. However, parallel with its compilation, the Upper Miocene and Pliocene litostratigraphic units were newly reinterpreted and the stratigraphic classification was modified by the Neogene-II working committee; this was in the frame of the Geological Committee of the Hungarian Academy of Sciences. The working committee approved many changes on the previous stratigraphic chart. As a result, several formations have been reclassified as members and some members and formations have been deleted from the official stratigraphic chart.

As a consequence, sometimes there is a contradiction between the nomenclature used in the legend of the map and the opinion of the Neogene-II working committee. The changes are described in the text of the explanatory book, but with respect tothe description of the formations there is no deviation from the text of the legend of the map. In cases where a change has been made, it is referred to it in the text and the current official name of the formation is given in brackets; furthermore, refererence is also made to changes made at the level of the stratigraphic unit. For instance, "Somló Fm" is written in the legend, but in the text "Somló Fm (Member)" appears. When only the lithological name is given in the legend of the map, the change is referred to in the text (for example: Bükkalja Lignite Member (Újfalu Fm).

Lacustrine claymarl, siltstone, carbonaceous clay (Taliándörögd Marl — 5M)

According to the detailed description of JÁMBOR (1980), this formation dominantly comprises dark grey, grey claymarl, marl and clayey siltstone beds; these beds frequently alternate with thin lignite, carbonaceous clay and huminitic clay beds. The lilac grey, light grey calcareous marl intercalations are characteristic of the Taliándörögd Marl. With the exception of a sand body, the thickness of which exceeds 10m, only thin, 20–40 cm-thick fine sand beds occur in the succession. The formation is underlain by Pre-Pannonian formations, or the Kálla and Kapolcs Limestone Members. The formation is overlain by the Nagyvázsony Limestone and, unconformably, by Pleistocene rocks. The characteristic fauna record includes the following species: *Congeria ungulacaprae, C. balatonica, Melanopsis impressa, M. martiniana.* The calcareous marl beds contain, exclusively, freshwater and terrestrial gastropod fauna (BENCE et al. 1990, JÁMBOR 1980). The thickness of the formation ranges between 30m and 100m (JÁMBOR 1990). Its occurrence is restricted to the so-called Nagyvázsony lagoon and it occurs only in the surroundings of Kapolcs, Nagyvázsony and Öcs. (The occurrence depicted north of Zalahaláp is a mistake on the map.) The succession was deposited in the Nagyvázsony lagoon, which was repeatedly isolated from Lake Pannon. As a consequence of the isolation, freshwater conditions gradually developed in the lagoon. These isolation events are indicated in the succession by calcareous marl layers, in which freshwater and terrestrial fauna can be found. According to JÁMBOR (1980), the variegated beds in the upper part of the member indicate that a drying-out process took place. The

Taliándörögd Marl is the heteropic facies of the Somló and Tihany Members (JÁMBOR 1980); as such, in the current lithostratigraphic classification, it is considered to be a member of the Újfalu Fm (*Taliándörögd Member*).

Shoreface sand, gravel, siliceous sandstone (Kisbér, Zámor, Kálla, Diás, Borsod Gravel — 4M)

The most noticeable, most exposed formations of the one time Lake Pannon are gravel, pebbly sand and sandstone beds of different ages and origins, respectively. The source areas of four of the pebble-bearing stratigraphic units (together marked as M4) were primarily the islands of Lake Pannon: namely, the present-day Transdanubian Range, the Mecsek and the North Hungarian Range. The material of the Borsod Gravel partly derives from the marginal area of the Pannonian Basin — i.e., from the West Carpathians. The same applies to the bulk of the material of the finer-grained formations which fill the basin. The material of the deltas on the western margin of the Little Hungarian Plain (assigned to the Kálla Fm) also originates from the margin of the Pannonian Basin — i.e. from the Eastern Alps. The lithostratigraphic classification of the pebble-bearing stratigraphic units is currently under revision.

Kisbér Gravel is made up of sand, pebbly sand, and well-rounded, grey, small-grained gravel (JÁMBOR 1980). Upwards the succession becomes finer. The pebble grains of the lowermost beds are coarser than those of the overlying bed; also moving upwards, the succession passes into pebbly sand and sandstone. Everywhere the underlying rock of the formation is pre-Pannonian rock, while the overlying formation is Szák Clay Marl. The thickness of the formation is small, being 0.2–14.5m, and the average thickness is 6–7m (CSILLAG et al. 2008). The formation is known to occur from the western margin of the Gerecse up until Sümeg. The characteristic fauna record includes *Congeria cjzjeki, C. partschi, and Lymnocardium secans*. Kisbér Gravel can be assigned to the upper part of the Conjungens Zone of the Late Miocene littoral mollusc zonation (MAGYAR et al. 2000); this is in accordance with the Paradoxus Zone age (SÜTŐNÉ SZENTAI 1991) of the overlying Szák Clay Marl. According to JÁMBOR (1996a), it is a marginal formation of once existing abrasional pebbly beaches; its extent can be followed to the inner part of the basin and it reaches over 10–12km. Everywhere the underlying rocks are Oligocene – Lower Miocene sandy-pebbly formations, and this indicates that the Kisbér Gravel was formed from their redeposited material.

Zámor Gravel was first described by JÁMBOR (1980) (the "Tinnye pearl-gravel member"). According to his description, the formation consists of alternating grey and off-white, small to medium-grained, well-sorted, 20–100 cm-thick pebbly sand beds; 80–98% of the material of the sand grains is quartz; the bulk of the pebbles are also made up of white or grey quartz and quartzite, but there are also chert, lydite, quartz-porphyry pebbles among them. The size of the well-rounded pebbles is a maximum of 3 cm, with the dominant size being 0.5–1cm (JÁMBOR 1980). In many cases it is deposited at the base of the succession of the former Lake Pannon; it is overlain by Csákvár Clay Marl, in which it appears as an intercalation. The thickness of the Zámor Gravel is usually 10–30m, but infrequently it is only 1–2m (JÁMBOR 1980). Its maximum thickness is 53.5m (borehole Söréd Sö–10; in the south-eastern foreland of the Vértes) (CSILLAG et al. 2008). It characteristically occurs in the south-eastern foreland of the Transdanubian Range where, according to JÁMBOR (1980), it can be followed until the area of Gyúró, Tárnok and Lajoskomárom. The formation, with the exception of the exposure at Tinnye, is poor in fossils. JÁMBOR (1980) mentions the species *Melanopsis fossilis* and *Congeria ornithopsis* as characteristic fossils. Zámor Gravel is made up of beds which were deposited in a delta or shallow pebbly beach environment. The extent of the formation indicates that the source area was not exclusively that part of the Bakony which is covered by the Csatka Fm. Pebbles from the area of Bicske, Pusztazámor and Sóskút could not have originated in the Bakony, since between the two areas the formation pinches out. The formation of the Zámor Gravel began in the Congeria onrithopsis biozone, being coeval with the oldest sediments of Lake Pannon. However, the appearance of the gravel member between the beds of the Csákvár Clay Marl proves that the transportation of the gravel material was repeated. Based on the occurrence and the age of the overlying Csákvár Clay Marl, the formation of the gravel lasted until the Pécsvaradensis microplankton zone (10.5 Ma).

Kálla Gravel is probably the most famous formation among the sediments of Lake Pannon. Its fame is related to the "sea of stones" of the Kál Basin, which is one of the most visited geological curiosities and spectacular sites of Hungary. Many publications are available on its occurrences in the Transdanubian Range, but the first summarized description of the formation (under the name "Kálla pearl gravel – quartzsand member") was made by JÁMBOR (1980). He assigned the dominantly delta sediments (today belonging to the Kálla Gravel) and the abrasional gravels — currently known as Diás Gravel (see below) — to one lithostratigraphic unit. The occurrences of Kálla Gravel in the West Mecsek and in the surroundings of Bükkösd were described by KLEB (1973). The bulk of the gravel material is quartzite and, less frequently, lydite and other types of metamorphite; however, chert, limestone and dolomite are also present. The average diameter of the pebbles is around 1 cm; the maximum size is 12cm. The ratio of sand to gravel varies, both horizontally and vertically. The sand is usually fine-grained and the material is quartz (sometimes in a proportion that is suitable for commercial use as an industrial raw material). In places a few heavy minerals occur as well. Due to the excellent sorting, the formation is usually structureless; however, locally, we can encounter small-scale trough cross-bedding, hummocky-cross lamination, parallel lamination and bioturbation (BUDAI et al. 1999). One of the most prominent features of the succession is that there

are steeply-dipping, 4–15 m-high fore-set beds underlying horizontal topset beds (Sztanó et al. 2010, Tóth et al. 2010). The underlying rocks are diverse: Ősi Variegated Clay, and Csákvár and Szák Clay Marl; however, pre-Pannonian formations also occur frequently. The formation is overlain by the Somló or the Tihany Formations (Member). Its thickness is usually 10–20m; the maximum thickness is around 50m (Budai et al., 1999). Kálla Gravel is known over a large area in the Transdanubian Range: from the Keszthely Mountains till the Gerecse. In the southern foreland of the Mecsek it can be followed from the WestMecsek eastwards, over a long section up to the granite area of Mórágy. Usually, the formation is poor in fossils. The fauna record around the Kál Basin was described by Magyar (1988), and that around Fehérvárcsurgó also by Magyar (1992). The flora was described by Hably (2013). Characteristic species in the fauna are: *Congeria* sp., *Lymnocardium* cf. *soproniense, L.* cf. *majeri, Unio atavus, and Melanopsis* cf. *fossilis;* characteristic flora species are: *Pinus* sp. and *Picea* sp. In the Transdanubian Range the age of the Kálla Gravel extends to the younger part of the Lymnocardium conjungens zone (Kál Basin), and the Lymnocardium ponticum (Fehérvárcsurgó) zone — namely, between ca. 10.5–8.6 Ma (Magyar 2010). The occurrences in the Mecsek are younger than 8 million years and can be assigned to littoral zones, coeval to the Congeria rhomboidea sublittoral zone (Sebe et al. 2015). The bulk of the Kálla Gravel was formed as relatively small Gilbert deltas; a part of the gravel and sand was spread in the environment of the deltas by longshore currents and wave action (Babinszki et al. 2003, Csillag et al. 2010, Sztanó et al. 2010). Kálla sand and gravel are excavated in many open pits, among which the quarries at Salföld, Fehérvárcsurgó and Billege are of industrial importance.

Diás Gravel has been listed as an unofficial unit among the Late Miocene lithostratigraphic units since 1996. Csillag (1996) distinguished this abrasional gravel from Kálla Gravel, which was primarily deposited in a delta environment. The material of the Diás Gravel is locally derived; it consists of gravel, conglomerate, debris or breccia, which formed the rocky coasts of Lake Pannon. As such, the gravels are made up of Palaeozoic, Mesozoic and pre-Pannonian Tertiary rocks (granite, sandstone, limestone, dolomite etc.). Both well-rounded gravel and angular to subangular breccia particles occur. The thickness of the formation is several metres, with a maximum of 8m. Away from the one time coast, it pinches out fast. It usually overlies the pre-Pannonian rock surface — in intercalations — and it may also occur in the Somló and Tihany Fm (Member). Its extent is restricted to the marginal parts of the mountains. The best known exposures are found in the Transdanubian Range (Budai et al. 1999, Csillag et al. 2008), in the Mecsek, and in the Velence Mountains (Gyalog, Horváth 2004, Gyalog, Ódor 1983). It contains no fauna; its age can only be assumed on the basis of the potential under- and overlying Pannonian formations. Its formation is related to the wave-dominated coastal zones of Lake Pannon: thus there are abrasional gravels, breccias (which formed in the supralittoral zone of the rocky coasts), and sediments (which accumulated below the wave-base).

A brief description of the *Borsod Gravel* Fm given by Peregi (1996) is also mentioned in the work of Gyalog (2005). On the basis of these works, the material of the pebbles is of crystalline rocks and Mesozoic carbonates. In the coarse-grained gravel, sandy gravel succession, there are several-metres thick intercalations of variegated clay and pebbly clay. The thickness of the formation ranges between 90m and 100m. It occurs north of the Sajó valley and can be followed to the Slovakian border. In the Slovakian area it is known as the Poltár Gravel Fm. Its age is uncertain. According to the conventional classification, it is "Lower-to-Upper Pannonian". This would suggest that the formation of the Borsod Gravel took place over an extremely long period (millions of years). This assertion can be excluded, however, on the basis of its relatively low thickness (90–100m) and its sedimentological character. According to Peregi (1996), the Borsod Gravel was formed as a basin-marginalluvial fan, while according to Jámbor (pers. comm.), it is of fluvial origin.

Lacustrine clay marl, sand, silt, variegated clay (Szák, Csákvár Clay Marl, Ősi Variegated Clay — 3M)

Formations marked as 3M were deposited in highly diverse sedimentary environments of Lake Pannon. The only common feature is that they were formed at the base of the lacustrine succession, at the time of the transgression of the lake. According to the interpretation of the Neogene-II working committee, Szák Clay Marl was deposited on an elevated, yet sublacustrine high, within the basins and in the vicinity of "islands". It is a heteropic facies of the Endrőd Marl Fm. The Csákvár Clay Marl was deposited in shallow coastal waters and is related to the islands of Lake Pannon (eg. some areas of the Transdanubian Range, such as the Mecsek). These areas were periodically desiccated. The Ősi Variegated Clay was formed from sediments deposited on a coastal plain with alluvial swamps.

After the detailed description by Jámbor (1980) only some recent publications have produced new information on the *Ősi Variegated Clay* Fm (Csillag et al. 2008, Kókay et al. 1991).

The formation is dominantly made up of mudstones. It mostly comprises grey, yellow-patched, green, greenish grey, grey, frequently variegated beds. Beside the clay, frequently claymarl, siltstone, and sandy, pebbly clay and sand beds occur; however, calcareous marl and limestone intercalations can be found in it as well. Locally, thin rhyolite tuff beds intercalate in the sedimentary succession (Jámbor 1990). Next to Öskü, lignite beds occur in a succession; this succession fills a karstic depression (Jámbor 1990). The fabric is frequently brecciated, angular and block-structured. Desiccation cracks, gypsum crack fillings and root traces are frequent. The beds are usually cut by shiny slicken-slide planes. The calcareous material is represented by small (2–30mm) white or yellowish white concretions. According to Jámbor (1980) the Ősi Variegated Clay

becomes finer upwards; pebbles and pebbly sand beds are characteristic of the lower section. The pebbles are quartz, quartzite, chert, but weathered, green phyllite occurs as well (CSILLAG et al. 2008; JÁMBOR 1980, 1990). The formation is present in the southern–south-eastern foreland of the Transdanubian Range, between Felcsút and Balatonkenese (CSILLAG et al. 2008, JÁMBOR 1980, 1990). Its presence has been detected also in the Vértes, and in the Gánt Basin (CSILLAG et al. 2008, GYALOG 2005). It unconformably overlies the underlying rocks. On the Neogene terrestrial areas of the Transdanubian Range, it was deposited on the Sarmatian Gyulafirátót Fm (BUDAI et al. 1999, JÁMBOR 1980). Its thickness varies between 7m and 90m; the average thickness is 15–25m (CSILLAG et al. 2008; JÁMBOR 1980, 1990). However, in several boreholes around Magyaralmás, it is underlain by Zámor Gravel (e.g. Ma–62) or Csákvár Clay Marl (Ma–10). Futhermore, formation is frequently overlain by the Csákvár Clay Marl; in the surroundings of Fehérvárcsurgó, however, the Kálla Fm is deposited on it (CSILLAG et al. 2008). According to JÁMBOR (1990), the duration of the formation of the Ősi Variegated Clay lasted longer in the Mór Trench than elsewhere. This fact explains why the stratigraphic conditions differ from those of other areas. JÁMBOR (1980) described a local succession around the Söréd–Magyaralmás–Fehérvárcsurgó area, where variegated clay is found between the Oligocene Csatka Fm and the Pannonian Kálla Formations. Thus it was supposed that its deposition occurred in multiple terrestrial phases from the Early Miocene up until the Late Miocene appearance of Lake Pannon. The Late Badenian Hidas Fm is intercalated (KÓKAY 2006) in the terrestrial series of the Fehérvárcsurgó Fcst–5 borehole; this indicates that the terrestrial deposition occurred before and after Late Badenian. The Ősi Variegated Clay contains very few fossils. Examples include small Cardiidae species, and there are a few freshwater gastropods in the limestone and huminitic clay beds. Large ostracodes are characteristic fossils in the calcareous marls. For the determination of the age of the formation, the *Mecsekia incrassata* organic-shelled microplankton provides useful information, since it marks the Sarmatian-Pannonian boundary zone (KÓKAY et al. 1991). The Ősi Variegated Clay was formed in a paludal and terrestrial environment. The exact age of the formation is not known. According to KÓKAY et al. (1991) the age of the dacite tuff under the Ősi Variegated Clay is 12.6±0.5 Ma; a more precise age cannot be given.

Csákvár Clay Marl was first described by JÁMBOR (1980). More recently CSILLAG et al. (2008) summarized all the available information on the formation. The bulk of the Csákvár Clay Marl Fm is made up of grey, light grey claymarl, clayey siltstone with thin intercalations of fine sand, silstone and huminitic clay beds. In the lower part of the formation grey, greyish white diatomite beds also occur (HAJÓS 1971, JÁMBOR 1971). The formation usually comprises layers of lamellar-conchoidal parting. Fibrous pyrite precipitations are frequently found in the sediment andthe underlying rocks are very diverse. It occurs on pre-Pannonian formations, as well as on the Ősi Variegate Clay and the Zámor Gravel. It is also possible that in the inner part of the Zámoly Basin, on the basis of the appearance of the oldest lacustrine fossils, it may conformably overlie the Sarmatian Kozárd Fm. It is usually overlain by Kálla Gravel or the Somló Fm (Member), and possibly also the by Csór Siltstone. According to JÁMBOR (1980), Csákvár Clay Marl occurs in the south-eastern foreland of the Transdanubian Range, between the Mesozoic and the Palaeozoic blocks in the forelands, as well as in the Zsámbék Basin. It also occurs in the Vértes, in the Gánt Basin (CSILLAG et al. 2008). Certain sections of some boreholes on the marginal parts of the Mecsek have also been assigned to the Csákvár Claymarl. The thickness of the formation ranges between 70m and 190m (JÁMBOR 1980), but in the south-eastern foreland of the Vértes it is only 10–130m (CSILLAG et al. 2008). Csákvár Clay Marl is rich in fossils. Its mollusc fauna was described by TÓTH (1971), and the available results have been summarized in the explanatory book of the Vértes (CSILLAG et al. 2008). Characteristic species include *Congeria ornithopsis, C. czjzeki, Lymnocardium secans, and Melanopsis bouei sturi*. Trace fossils, like the *Pectinaria ostracopannonicus,* are also frequently found (JÁMBOR, RADÓCZ 1970). Its rich diatoma assemblage was described by HAJÓS (1971). Organic-shelled micro plankton and sporomorph assemblages have been described more recently by SÜTŐ-SZENTAI, SELMECZI (2004). Csákvár Clay Marl was dominantly deposited in shallow, partially isolated waters near the islands of the Pannonian Basin. Its heteropic facies is the Endrőd Fm, and this was formed in the area of the deep basins, away from the existing coastline. According to HAJÓS (1971) the Diatoma assemblage indicates a nearshore, brackish water environment, characterised by a fluctuating water level (7–60m). According to SÜTŐNÉ SZENTAI (1991), the formation of the Csákvár Clay Marl lasted from the oldest, Ultima Zone, through the Pannonicus and Oblongus Zones, until the Pecsvaradensis Zone. According to MAGYAR (2010), the radiometric age of the formation is 11.6–10.6 Ma.

The succession of the *Szák Clay Marl* consists of grey, lamellar-conchodial, lamellar silty claymarl, and clayey siltstone. It is extremely homogenous. It significantly differs from the diverse succession of the Csákvár Clay Marl (which comprises travertine, calcareous marl, and gravel and sand intercalations). The formation is underlain by Kisbér Gravel on the western margin of the Transdanubian Range. Further away, it is deposited on older Palaeogene or Mesozoic formations (JÁMBOR 1980). It is overlain by the Somló Fm and is known on a large area on the western margin of the Transdanubian Range — namely, in the area of the Keszthely Mountains and in the Tapolca Basin. Its thickness is several tens of metres and it exceeds 100m toward the basin, on the the basin's marginal parts (JÁMBOR 1980). It is rich in macrofauna and characteristic molluscs are *Congeria czjeki, C. partschi, Lymnocardium triangulatocostatum, Paradacna abichi, and Valenciennius reussi*. In Szák Clay Marl trace fossils are also frequently found: JÁMBOR (1980) described burrows named as *Pectinaria ostraco-pannonicus*, a *Spirosiphonella pannonica* and *Minisiphonella transdanubica*. Szák Clay Marl was deposited in a shallow sublittoral environment on the elevated basement highs, yet it was covered by the lacustrine waters of Lake Pannon.

According to the organic-shelled micro plankton zonation described by SÜTŐNÉ SZENTAI (1991) it was deposited in the Paradoxus Zone. According to MAGYAR (2010), the fauna record of Szák Clay Marl on the western margin of the Transdanubian Range marks the upper part of the Lymnocardium soproniense Subzone of the Congeria czjzeki Zone. According to the geological map of Hungary (GYALOG 2013), formations marked as 3M have mappable size surface occurrences only in Transdanubian Range.

Lacustrine clay, silt, sand; carbonaceous clay, lignite (Somló, Tihany Fm, Torony Lignite — 2M)

Stratigraphic units marked as 2M were previously regarded as formations. According to the proposal of SZTANÓ et al. (2013), formations previously known as the Somló and Tihany Formations are now regarded as members of the Újfalu Fm. The term "Torony Lignite Fm" has been discarded by the Neogene-II working committee, and the beds have been assigned to the Bükkalja Lignite Member. The first description of the three stratigraphic units marked as 2M can be found in the work of JÁMBOR (1980).

In the lower part of the *Somló Fm* (*Member*), relatively thick but very fine to fine-grained sand has been deposited; above this two-thirds of the member is composed of alternating sand, siltstone and clay beds (JÁMBOR 1980). The succession is of a fining-upward character. On the southern and western margin of the Keszthely Mountains the sand is strongly cemented and bulk of the rocks are made up of thin-bedded sandstone (so-called "card stone" or "card sandstone"). In the fossil-rich strata, locally, *Congeria ungula caprae* occurs in rock-forming quantities. Other typical mollusc species are *Dreissena auricularis*, *Lymnocardium majeri*, *L. apertum*, *L. penslii*, and *L. variocostatum* (JÁMBOR 1980). A special species of its flora is the *Quercus kubinyii*. Other characteristic elements of the flora are: *Liquidambar europea*, *Platanus leucophylla* and *Salix varians* (HABLY 2013). In the siltstone and claymarl beds, *Arenicola marina* burrows frequently occur (JÁMBOR 1980). The maximum thickness of the Somló Fm (Member) is around 150–160m (BUDAI et al. 1999, CSILLAG et al. 2008, JÁMBOR 1996b), and it was was deposited in the prodelta to deltafront region.

The *Tihany Fm* (*Member*) is made up of densely alternating sand, clay, siltstone, huminitic clay, carbonaceous clay and lignite beds It also contains cm-thin dolomite intercalations (JÁMBOR 1980). The most recent description of the key section of the formation, — the Tihany, Fehérpart — has been presented by SZTANÓ et al. (2013). The fossil-rich fauna of the Tihany Fm (Member) was described by MÜLLER, SZÓNOKY (1988). Characteristic mollusc species are: *Lymnocardium decorum*, *Prosodacnomya carbonifera*, *C. balatonica*, *Viviparus sadleri*, *Melenopsis cylindrica*, *M. decollata, Theodoxus ecarinatus,* and *T. radmanesti*. In the mammal fauna, the *Allospalax petteri* and the *Crusafontina kormosi* are important age indicators. The thickness of the formation on the Balaton Highland type-area is a maximum of 60–80m (BUDAI et al. 1999). The Tihany Fm (Member) was deposited on a delta plain, in interdistributary bays, in marshes, and in distributary channels (SZTANÓ et al. 2013). From NW to SE, from the Little Hungarian Plain to the Drava basin, the Somló and Tihany Formations (Members) become younger (from around 9.5 Ma to 5.5 Ma).

A detailed description of the (earlier named) *Torony Lignite* was also made by JÁMBOR (1980). Similarly to the Somló and Tihany Formations (Members), this member is also mostly (85%) made up of clay and silt. Successions with significant lignite seams are mentioned only in the western part of Hungary. After Jambor's study and interpretation of the formation, further detailed work did not continue. JÁMBOR (1996c) described the Torony Fm as a stratigraphic unit identical with the Bükkalja Fm. On the 1:100,000-scale geological map of Hungary the Torony Fm is not depicted; around Szombathely, where it is widespread, only the Tihany Fm appears (GYALOG 2005). Its poor fossil record consists of freshwater and terrestrial forms (JÁMBOR 1980). The flora of the Szombathely occurrence was described by HABLY (2013); the main species of the typical paludal flora are the *Glybtostrobus europaeus,* the *Byttneriophyllum tliifolium,* the *Alnus cecropiifolia, A. menzelii, and* the *Myrica lignitum* etc. *Quercus kubinyii* is also worth mentioning. The formations marked as 2M crop out only in Transdanubia; however, in reality, the surface occurrence of the three formations is smaller than depicted. On the southern part of the Little Hungarian Plain, the Tihany Fm appears on the geological map produced by GYALOG (2005) (see Zagyva Fm). JÁMBOR (1980) assigned the surface occurrences of the area (Hosszúpereszteg, Pannonhalma) to the Torony Member. His description, however, reveals deposits which are now considered as the Zagyva Fm. The lignite-bearing facies of the Torony Member is identical with the Bükkalja Member of the Újfalu Fm, though other occurrences of the member mentioned by JÁMBOR can possibly be assigned to the Zagyva Fm. The age of the lignite-bearing part of the Torony Member is given as 7.3–6.7 Ma by MAGYAR (2013), who seismically correlated it with the Prosodacnomya daniellii zone of the Iharosberény borehole. It is the same as the age of the Bükkalja Fm. During this period, however, between the depositional area of the Torony Member in the western part of Transdanubia and the delta plain of Lake Pannon in southern Transdanubia, a vast alluvial plain developed. If accept the so-determined age of the formation, then the lignite-bearing succession of the Torony Member was not a formation of Lake Pannon, but that of a separate, smaller lake or a marshy area.

Lacustrine limestone, calcareous marl (Nagyvázsony, Kapolcs Limestone — 1M)

Two formations of a different age but deposited under similar conditions have been combined on the map. The older — *Kapolcs Limestone* — is faded grey, white, hard and compacted, and it is made up of 5-30 cm-thick beds (JÁMBOR 1980).

Locally, the topmost layers of the Kálla Gravel are also cemented by this limestone. From the thickest successions of the limestone JÁMBOR (1980) described gravelly intercalations. These pebbles are identical with that of Kálla Gravel. The Kapolcs Limestone is underlain by Kálla Gravel, or by rocks which were previously assigned to the Imárhegy and Csór Silt (JÁMBOR 1990); however; these currently form the members of Csákvár Clay Marl Fm. The formation is overlain by Taliándörögd Marl. It frequently contains brackish-, and freshwater gastropods: *Planorbis* sp., *Cepea* sp., *Lymnea* sp., *Melanopsis fuchsi*, and *Hydrobia* sp. (JÁMBOR 1980). The thickness of the limestone ranges between 0.4 and 10m. Its occurrence is restricted to two, relatively small isolated basins and these are surrounded by Triassic carbonate rocks: these basins the so-called "Nagyvázsony lagoon" and the Gyulafirátót Basin (JÁMBOR 1990). There is no direct data on the age of the Kapolcs Limestone. It partly interfingers with the Kálla Gravel (4M); on the basis of this, its formation started at the same time and continued even after that.

Since the extent of the *Nagyvázsony Limestone* is much larger than that of the Kapolcs Limestone, its geological and stratigraphic importance is much larger as well. A typical sample is faded brown, brownish grey, non-porous, hard, micro-crystalline limestone, and siliceous limestone. It forms 10–50 cm-thick beds. The freshly cut surface frequently has the odour of bitumen. On the surface, large blocks of limestone can usually be seen. However, in the succession there also occur fine-grained siliciclast and huminitic clay, as well as clay beds with plant fragments (BENCE et al. 1990, MÜLLER, MAGYAR 2008). Some of the beds contain gastropods in rock-forming quantities. According to borehole data, in many cases the proportion of the limestone is subordinate; the carbonates are only partly diagenized and they show the character of chalk. In a similar proportion, one can also find clay with calcareous nodules, (rarely) bentonitic clay, and carbonate-free red clay beds (BUDAI et al. 1999). The fauna of the formation includes freshwater and terrestrial gastropods (*Planorbis* sp., *Cepea* sp., *Lymnea* sp., and *Tachaeocampylaea doderleini*). BARTHA (1971) described *Unio wetzleri* in the sand intercalation of the travertine of the Várpalota section. MÜLLER, MAGYAR (2008) described rich mollusc fauna in the Buda Hills from the succession of the Nagyvázsony Limestone: *Anodonta* sp., *Dreissena* sp., *Melanopsis fuchsi*, *Melanopsis sturi*, *Theodoxus radmanesti*, *Planorbarius* sp., Planorbidae sp., *Dreissena* sp., *Lymnocardium decorum*, *Melanopsis* sp., *Theodoxus* sp., *Viviparus* sp., *Micromelania* cf. *laevis*, *Hydrobiidae* sp., *Valvata* sp., *Stagnicola* sp., *Anisus* sp., ?*Mesodontopsis* sp., *Gastrocopta nouletiana*, *Carychium* cf. *sandbergeri*, and *Vertigo angustior oecsensis*. The Nagyvázsony Limestone is mostly underlain by the Tihany or Taliándörögd Members of the Újfalu Fm; however, locally, it overlies pre-Pannonian beds It is mostly overlain by Pleistocene rocks, though in the surroundings of Nagyvázsony it is locally overlain by the lava flow remnants of the Tapolca Basalt Fm. JÁMBOR (1980) described a succession of 40–45 m-thick claymarl, clay and sand above the travertine in the Bakonykút Basin, which contains only a few terrestrial mollusc fragments. It is currently assigned to the Vértesacsa Member of the Zagyva Fm. Nagyvázsony Limestone was formed close to the karst ranges of the Transdanubian Range, on the marginal or upper part of the delta plain. It was deposited in small lakes and isolated bays — far away from the main transportation routes — and charged by karst springs. Smaller changes of the lacustrine base level temporarily interrupted the spring activity, and thus also affected the formation of the limestone. The thickness of the Nagyvázsony Limestone varies between 30m and 40m. The formation is known on the margins and in the inner basins of the Transdanubian Range, from the Keszthely Mountains until the Buda Hills. The Nagyvázsony Limestone partly overlies the Újfalu Limestone, and partly interfingers with its upper part on the Balaton Highlands (BUDAI et al. 1999). According to MÜLLER, MAGYAR (2008) and KORDOS (pers. comm.), Nagyvázsony Limestone can be assigned to the MN10 vertebrata zone (9.7–8.7 Ma), and to the *Lymnocardium decorum* mollusc zone (8.0–8.7 Ma) in the Buda Hills. The vertebrate-bearing red clays which fill up fissures and cavities of the travertine have been assigned to the MN12 zone (7.5–6.8 Ma); thus the limestone is certainly older than this (MÜLLER, MAGYAR 2008).

MIOCENE–PLIOCENE

Fluvial–lacustrine–paludal sand, clay, lignite (Nagyalföld Variegated Clay, Zagyva Formation, Bükkalja Lignite — MPl)

On the map, two types of deposits (the depositional environments of which were totally different), are depicted and these are combined with the same sign. The Nagyalföld Variegated Clay and the Zagyva Fm include channel-fill and floodplain sediments of rivers which filledup Lake Pannon. However, the Bükkalja Lignite, like the Torony Lignite (JÁMBOR 1996c), belongs to what was the delta plain of Lake Pannon. According to the current stratigraphic classification, it is a member of the Újfalu Fm. The combination of deltaplain lignites with the fluvial formations is based on the concepts of GAJDOS et al. (1983) and JUHÁSZ (1994); with regard tothe Bükkalja Lignite, they represent the heteropic facies of the Zagyva Fm and the Nagyalföld Variegated Clay. The map extension of these formations depicted with this sign on the map does not include, however, the Vértesacsa Member of the Zagyva Fm (CSILLAG 2008) (formerly a member of the Vértesacsa Fm) between the Vértes and the Velence Mountains.

The *Zagyva Fm* comprises densely alternating; dominantly medium to very fine-grained sand, sandstone, siltstone, clay and calcareous clay beds. The formation contains many carbonized plant fragments and, frequently, lignite layers. The thickness of the sand and sandstone bodies often reaches 10m (GYALOG 2005). The succession comprises channel-belt and floodplain sediments of the alluvial plain of the river system which once carried sediment into Lake Pannon, as well as sediments deposited in the small, ephemeral lakes which existed on the floodplains. Thick palaeosols — often with carbonate-accumulation horizons — frequently occur (CSILLAG 2008). UHRIN et al. (2011) described vertically accreted, narrow sand bodies in the foreland of the Vértes; this is a feature which indicates the one time presence of anastomosing rivers. Channel fills of braided rivers occur only in a few exposures, and these are usually close to coeval faults. Meandering rivers were characteristic in the Gödöllő Hills and these rivers represent one of the rare surface occurrences of the formation (UHRIN, SZTANÓ 2007). The depth of the respective channels was around 8–9m or 5m. The order of the magnitude of the former is characteristic of the Tisza; that of the latter is typical of the tributaries of the Tisza. The formation is relatively poor in fossils. One of its two important vertebrate occurrences is at Baltavár (Bérbaltavár).

According to the new investigation of its Hipparion fauna, the two most frequent species are *Hippotherium intrans* and *H. "microdon"* (KAISER, BERNOR 2006). HALAVÁTS (1923) described 17 mollusc species from the Baltavár occurrence; among the many new species were *Margaritifera flabellatiformis* (mentioned as *Unio Wetzleri*) and *Tachaeocampylea doderleini*. The fauna of the railway cut at Gödöllő was described by MOTTL (1939): *Bunolophodon longirostris – Dibunodon arvensis, Dicerorhinus megarhinus, Hipparion crassum, and Cervus pardinensis*. The formation infrequently contains molluscs; yet, from the beds around Hosszúpereszteg JÁMBOR (1981) described *Margaritifera flabellatiformis* and *Tachaeocampylea doderleini*. The description of the plant fossils of the formation has been given by Hably (2013), who described the flora of the Győr-Sashegy, Sótony, and Hosszúpereszteg occurrences. The Zagyva Fm occurs everywhere in the basins, under the Pleistocene successions. It is also present on the surface, on the margins of the basins, in the hilly regions: namely, in the Zala, Vas and Gödöllő Hills, and in the southern forelands of the Vértes, the Cserhát, the Mátra and the Bükk. According to the interpretation of the sections by MAGYAR (2010), and the analysis of freshwater-terrestrial beds occurring in the overlying brackish water successions, the Tihany Fm (Member) depicted on the Little Plain belongs to the Zagyva Fm. In the basins, the Zagyva Fm is underlain by the Újfalu Fm On the marginal areas it may overlie the older sediments of Lake Pannon, or be found on the surface of older formations with erosional unconformity.

The *Nagyalföld Variegated Clay* used to be regarded as a separate formation, but currently it is a member of the Zagyva Fm. It is made up of bluish grey sand and grey, yellowish grey, reddish brown, variegated clay beds, in which (frequently) lignite intercalations and pebbly sand beds also occur (GYALOG 2005). The thickness of the Zagyva Fmormation (without the Nagyalföld Veriegated Clay) is around 10–100m on the marginal areas. In the basins, its maximum thickness exceeds 1000m (GYALOG, 2005). The thickness of the Nagyalföld Variegated Clay ranges between some metres to some tens of metres on the margins. According to GAJDOS, PAP (1996), in the area of the basins several hundreds-of-metres-thick successions are known. The Nagyalföld Variegated Clay is underlain by the Zagyva Fm in the basins, and by older Lake Pannon or pre-Pannonian formations on the marginal areas. The age of the Zagyva Fm can only be estimated based on the data of a few localities. Southwards, parallel with the filling-up of Lake Pannon, the bottom of the fluvial succession becomes increasingly younger. In accordance with this, the age is 9 Ma on the Little Plain, while in the south-eastern part of the Great Plain it is ca. 5 Ma. According to MAGYAR et al. (2007), the Baltavár beds belong to the C4n polarity zone (8.11–7.58 Ma); according to this, the fauna can be assigned to the MN11–12 zones (9.0–7.0 Ma). The same fauna was placed in the MN12 zone by KAISER, BERNOR (2006), who assumed an age of 7.5–7.0 Ma. Given the interpretation of MOTTL (1939), the age of the Gödöllő fauna is Early Pliocene. This was verified by JASKÓ, KORDOS (1990), who assigned the Gödöllő fauna to the MN14 zone (4.7–4.2 Ma). The bulk of the Nagyalföld Variegated Clay is of Pliocene Age; however, its formation continued into the beginning of the Pleistocene (GAJDOS, PAP 1996).

The *Bükkalja Lignite* comprises grey, bluish grey and variegated clay, sand and lignite beds. The thickness of the lignite seams can attain 10–15m. The depicted surface occurrence of the Bükkalja Lignite is restricted to the southern foreland of the North Hungarian Mountains. The formation is relatively rich in fossils; its vertebrate fauna was described by BERNOR et al. (2003). The rich flora assemblage includes remnants of the outstanding swamp cypress forest (*Taxodioxylon germanicum*) which existed at present-day Bükkábrány. From the flora (which includes a relatively small number of species), several species have been described, including *Ginkgo adiantoides, Glyptostrobus europaeus* and *Alnus menzelii* (HABLY 2013). The sediments of the Bükkalja Lignite member were deposited on the delta plain of Lake Pannon. Their formation might be related to an intensive transgression event (JUHÁSZ et al. 1996; MAGYAR, SZTANÓ 2008). The age of the Bükkalja Lignite is Late Miocene. According to BERNOR et al. (2003), the vertebrate fauna of Hatvan belongs to the MN12 (8.2–7.0 Ma) zone. However, according to MAGYAR (2013) — referring to a personal communication from Kordos — it might be assigned to the MN13 zone. Its base can be correlated — by means of seismic profiles — with the Prosodacnomya dainellii zone; its formation possibly occurred between 7.5 and 6.7 Ma (MAGYAR 2013). Its depositional environment and age are identical with the lignite-bearing beds of the Torony Lignite of the West-Transdanubian Region (MAGYAR 2013). The lignite seams of the Bükkalja Lignite are currently exploited at Gyöngyösvisonta and at Bükkábrány.

MIOCENE–PLEISTOCENE

Basalt, basalt tuff, subordinately geyserite (Salgóvár, Tapolca, Bár Basalt — MQ)

There were many volcanic eruptions in the area of the Carpathian Basin between the Late Miocene and the Middle Pleistocene. As a result of this volcanic activity, characteristicalkali basalts were formed. The only exception is the ultra-alkaline *Bar Basalt*, the material of which is leucitite (HARANGI et al. 1995). In Hungary, basalt volcanic formations crop out on: (i) the Little Hungarian Plain (ii) in the area of the Bakony (iii) in the area of the Balaton Highland (*Tapolca Basalt*) (iv) in the Medves area (*Salgóvár Basalt*) and (v) in the SE-Transdanubian village of Bár (*Bár Basalt*). Due to the different typesof volcanic activities and the degree of erosion of the volcanic formations, the remnants of the basalt volcanoes are made up of rocks from diverse depositional environments. The most typical eruption type was maar-volcanism (MARTIN, NÉMETH 2004). The craters thus formed were mostly filled with lava flows and lava lakes. Their remnants are represented by the "mezas" of the Tapolca Basin (Badacsony, Szent György Hill), and the Somló and the Ság Hill on the Little Hungarian Plain. Erosional processes denuded the tuff rings of the maars. The pyroclastic rocks of explosive eruptions occur mostly where the eruption was not followed by the formation of lava lakes and lava flows (e.g. Szigliget, Tihany and the maars of the Little Hungarian Plain). In the crater lakes of the craters, diverse sediments were deposited and these range from coarse volcano-sediments, through to alginite (oil shale), and then until the geyserite of the thermal springs of the post-volcanic activity. In the last phase of the volcanic activity cinder cones (eg. Bondoró) were formed. Lava sheets are known to occur only on some hills: the Agár-tető and the Kab Hill. In the area of the Kovácsi Hill the basalt lava formed subvolcanic bodies and these were trapped in shallow depths. They reached the surface after the denudation of the overlying sediments. Locally, the erosion denuded the volcanic structures to a significant extent, thus exposing the deeper zones as well. Such a diatreme formed the little hill which can be found in the middle part of the Kál Basin (Kereki Hill) (NÉMETH et al. 2003). The volcanic activity lasted for ca. 6 million years. The oldest eruption of the Tihany Peninsula occurred ca. 8 million years ago; eruptions in the Medves areas and in Bár took place ca. 2 million years ago. On the Slovakian side of the Medves area the youngest eruptions probably occurred in the Middle Pleistocene (VASS, ELEČKO 1992).

PLIOCENE

Alginite, diatomite, bentonite (Pula Alginite — Pl)

The alginite (oil shale), diatomite and bentonite beds are situated in the craters of the one-time volcanoes. Those craters (maars), in which relatively large crater lakes were formed, developed during the phreatomagmatic eruptions of the intracontinental alkali basalt volcanism; this volcanism lasted from the Late Miocene until the beginning of the Pleistocene. In the closed, drainless lake basins, not only debris from the walls of the crater and from the surrounding tuff ring accumulated, but also large amounts of organic material. The bentonite laminae are composed of expansive clays, which were formed as a result of the weathering of the accumulated volcanic ash and debris. The source of the organic material was primarily the *Botryococcus braunii* green algae colony of the lakes. The alginite is represented by thin (less than one millimetre thick) laminae, which were deposited in an isolated basin, in an environment characterised by an oxygen deficit. The periodically proliferating, silica-shelled diatoms formed separate diatomite laminae. Due to the rapid sedimentation, the filling-up of the crater lake occurred over a relatively short time. As such, the volcanic activity resulting in the formation of the craters is not much older than the sediments of the lake. The age of the maar of Pula is ca. 4.25 Ma; the data for the Várkesző crater show large differences in age, ranging between 3 and 5.55 Ma (BALOGH et al. 1986). The distribution of the alginite, the diatomite and the bentonite is restricted to the area of the Little Hungarian Plain and the Bakony (the maar craters of Gérce, Egyházaskesző, Várkesző and Pula). According to JÁMBOR (1996) the thickness of the formation is several tens of metres; the maximum thickness attains 90m. Bentonite is still excavated in Egyházaskesző, while in the mines of Gérce and Pula alginite is periodically excavated.

PLIOCENE–PLEISTOCENE

Travertine (15Q)

Travertine occurs at many places in Hungary — what is more, its formation still occurs in the streams of mountainous areas. Extensive occurrences are known in the area of the Gerecse and the Buda Hills. According to KELE (2009), the travertines of both areas differ from those which are formed today from cold karst water; this is because the development of

the former was related to thermal karst waters. The sedimentology and depositional conditions of the travertines are quite diverse. In many cases they cemented the gravel-sand material of terraces into conglomerate, while at other places well-bedded, frequently laminitic beds can be observed in them; however, massive, unlayered beds are known as well. The investigations of KELE (2009) determined that the Gerecse is characterised by relatively low-temperature travertines, while those of the Buda Hills are partly related to high-temperature thermal waters. According to KELE et al. (2011), the precipitation temperature of the travertines of the Rózsadomb area of Budapest exceeded 20 °C — it could even have attained 60–65 °C. The age of the thermal water activity is 350,000 years. However, most of the travertines of Buda were also formed under lacustrine conditions (Üröm Hill, Budakalász). Furthermore, cones were typically formed in the Gerecse and in the Buda Hills (KELE 2009). The thickness of the travertine ranges between several metres and several tens of metres. The oldest occurrences shown on the map were probably formed at the end of the Pliocene, while the youngest ones developed during the Late Pleistocene. The rock has been mined since the Roman age. Travertine quarries currently operate in the area of Süttő, in the Gerecse, and in the surroundings of Budakalász (in the Buda Hills).

PLEISTOCENE

Infusion loess, clayey loess (14Q)

The so-called *infusion loess* is the one among the many loess types that raises most questions. RÓNAI (1991) distinguished the so-called loess-like formations from the "real" or "typical" loess types. These loess-like formations are dominantly made up of silt-sized grains, and were deposited on a wet surface in still water. He also drew attention to the possibility of the secondary redeposition of the dust which had fallen into the water. As a consequence, it is difficult to decide whether the fallen dust has accumulated or the material was redeposited by the water. Staying strictly with the definition of loess, these formations cannot be considered loess formations. According to GYALOG (1996), the material of the infusion loess is aeolian dust which was deposited in water, or material that was leached as a result of the water coverage. "Infusion loess" is more compacted than typical loess; its carbonate content is less and it is mixed with fluvial sediments in the succession. The composition of the grains varies; locally, the proportion of the sand is higher, while at other places this is the case with clay. According to PÉCSI (1993), the carbonate content is relatively high (10–20%). The map depicts only some patches and these are in the vicinity of the Tisza and Körös Rivers. The thickness of this "loess" ranges between 0.5m and several metres. According to PÉCSI (1993), the infusion loess was deposited during the last glacial (pleniglacial) period, juste fore the coldest and driest period.

The *clayey loess* is depicted on the map as 13Q, together with the other loess types of the loess sequence.

Loess sequence (loess, sandy loess, loessy sand, palaeosol — 13Q)

The study of the extremely diverse loess sequence known to occur everywhere in Hungary has a century-old tradition within the geological-geomorphological research of the Quaternary (HORVÁTH, BRADÁK 2014). According to the lithological composition and the depositional environment, different types can be distinguished.

The *"typical" loess* is represented by unbedded, massive formations and was formed from wind-transported dust. Dominantly, it is made up of silt-sized siliciclasts and its carbonate content is significant, sometimes being as much as 30%.

The *clayey loess, brown loess* is primarily known to occur in the western part of the Transdanubian region. It was formed in more humid areas. It is characterised by less carbonate content and higher clay content than the typical loess. It is partly made up of fallen dust, partly of the redeposited material of the slopes. KAISER, GYALOG (2005) assigned to this type the loess types described as clayey loess, loess-loam, brown earth and glacial loam.

The *slope loess* is mainly a weakly-bedded or medium-bedded formation, composed partly of redeposited slope material and partly of fallen dust. It forms sand-silt beds, alternating frequently with granules to fine gravels, locally, coarser gravel beds. The slope loess forms lenses or thin bands, and possibly also some several metres-thick intercalations in the typical loess; or it may form its underlying rock.

The *sandy loess, loessy sand* is generally made up of fallen dust and wind-blown sand as well as locally, redeposited deluvial material. The *infusion loess* is described in detail at formation "14Q".

As a result of soil formation beginning in the interval periods of the loess formation, *palaeosol horizons* may divide the loess sequences. In the older loesses red, mediterranean-type soils are characteristic, while in younger loesses brown forest soils are a typical feature; in the youngest loesses chernozem-type soils are a distinguishing presence. The carbonate content of the loess, precipitated as a result of soil formation and due to the effect of the groundwater, forms carbonate concretions (so-called "loess dolls") within the loess.

The maximum several cm-thick *tephra layers* were formed by the accumulation of the material from distant volcanic eruptions. These layers are important index horizons (HORVÁTH 2001).

The respective thicknesses of the loess sequences are extremely diverse. The thickest loess sequence in Hungary is found in the Tolna Hills (KOLOSZÁR, MARSI 2010). Its thickness here is 97m. However, at many places a loess sheet only 2–5 m-thicks covers the older beds Loess are the most extensive superficial formation in Hungary. It occurs on some part of the area of every region. In the Transdanubian region it mainly occurs in the Alpokalja – Vas Hills, in the Zala, Somogy, Tolna and Baranya Hills, as well as in the Mezőföld. East of the Danube it covers large areas on the northern margin of the Danube–Tisza Interfluve (Gödöllő Hills), especially in its southern part; it also occurs on the loess plain of Bácska, and on the Hajdúhát in the Tiszántúl Region. Loess is present in the inner and marginal parts of the Hungarian Central Range as well. The oldest loesses of Hungary are around 1 million years old (KOLOSZÁR, MARSI 2010), while the youngest ones are ca. 14–15 thousand years old (THAMÓ-BOZSÓ et al. 2010).

Proluvial sediments (12Q)

The formation of the proluvial sediments (alluvial fans) which occur in the direct foreland of the valleys on the southern, south-eastern margin of the Hungarian Range is related to periodic watercourses. The coarse debris that partly makes up the alluvial fans consists of clasts of varying roundness and size (for example, there are blocks which attain 1 metre diameter). The source of the clasts was the large amount of debris on the surface of the mountains. This debris was formed in cold weather as a result of frost weathering. The large proluvial alluvial fans were mostly formed in the forelands of the dolomite and volcanic mountains (the margin of the Keszthely Mountains, the Várpalota Basin, SE margin of the Vértes, southern margin of the Mátra, and the Bükk). The thickness of the formation ranges between 1 and 25m. Alluvial fans were formed from the Early Pleistocene until the Holocene. According to KAISER, GYALOG (2005), alluvial fans were formed on the top horizon of the Cserehát in the Early Pleistocene, while in the forelands of the Mátra and the Bükk they developed during the Early and Middle Pleistocene. Since then these sediments have been redeposited by slope movements. In the foreland of the Transdanubian Range most of the depicted alluvial fans were formed during the Late Pleistocene (BUDAI et al. 1999, THAMÓ-BOZSÓ et al. 2010).

Red clay, variegated clay (Lower–Middle Pleistocene — 11Q)

The brick red to grey variegated clay and red clay beds are eluvial formations; these formationswere slightly redeposited, partly by slope movements. They primarily occur in hilly areas.They are generally overlain by loess and thus they rarely occur on the surface. The map depicts the outcrops of the red clays of the Pest Plain around Kistarcsa and Maglód. The thickness of the red and variegated clay beds varies between several metres and several tens of metres (GYALOG 2005). The red and variegated clay depicted on the map is of Early and Middle Pleistocene age.

Fluvial sediments (Lower–Middle Pleistocene — 10Q)

The Lower–Middle Pleistocene fluvial sediments comprise the remnants of alluvial fans, basins and terraces; these formations are made up of series of gravel, pebbly sand, sandy gravel and sand beds. They mostly occur in patches and in few casesthey can be followed to a significant extent. The old Pleistocene fluvial formations depicted on the map are all found in the Transdanubian region, with the exceptions of one occurrence along the Ipoly, and another on the Pest Plain. Significant occurrences include the oldest terrace remnants of the alluvial fan of the Danube on the Kisalföld (Little Hungarian Plain), the gravel sheet of the Rába on the Kemeneshát, as well as the remnants of the old terraces of the Danube on the Győr–Tata terrace region and in the Gerecse. One of the oldest known Lower Pleistocene gravel occurrences is located next to Városhídvég. Here, a rich fossil assemblage has been exposed from the remnants of the gravel basin of Kenese–Városhídvég, as described by LÓCZY (1913) and KROLOPP (1978). The old fluvial sequences are usually highly denuded. Fluvial successions of significant thickness (exceeding even 20m) occur on the alluvial fan of the Kisalföld (Little Hungarian Plain) and in the northern foreland of the Gerecse, where the travertine deposited on the terrace protected it from erosion. The age of the old fluvial sediments has been determined by the vertebrate and mollusc fauna record. The deposition of the formations occurred during the Early and Middle Pleistocene, but in the case of the terraces of the Gerecse, it can also be assumed that the deposition had already started at the very end of the Pliocene.

Fluvial sediments (Middle–Upper Pleistocene — 9Q)

To this category belong the Middle and Upper Pleistocene fluvial alluvial fans, and the piedmont foreland fluvial sediments and terraces. They are made up of successions of varying grain size (from gravel to clayey beds), the thickness of which is several metres to several tens of metres. The thickest examples are the terraces of the Danube and the successions of the Tiszántúl. On the geological map, sediments depicted as Middle and Upper Pleistocene fluvial sediments occur on the Little Hungarian Plain, in the Tiszántúl Region and in the southern foreland of the North Hungarian Mountains. The age

of the depicted formations, primarily in the Tiszántúl Region, is younger than Middle–Late Pleistocene (the age shown in the legend). According to the most recent studies, the age of the alluvial fan of the Maros River is Holocene to Late Pleistocene (SÜMEGHY et al. 2013).

Fluvial-aeolic sand (Upper Pleistocene — 8Q)

This formation is made up of alternating aeolian and fluvial beds, fluvial beds locally affected by aeolian redeposition, and barely moved aeolian accumulations, composed of fluvial sand. The fluvial–aeolian sand is characteristic of the Transdanubian region. East of the Danube it is depicted on the Pest and on the Solt Plains, as well as in the Gödöllő Hills. Its typical thickness is 5–10m (Kaiser, GYALOG 2005). The age is usually Late Pleistocene or, infrequently, Holocene.

PLEISTOCENE–HOLOCENE

Slope (deluvial, slide, collapse, solifluction) formations (7Q)

This group includes formations of diverse lithology, which are found in all hilly and mountainous regions of Hungary. Slope sediments formed on solid rocks are mostly characteristic on volcanic areas, where they consist of the coarse blocks of the periglacial block streams that were formed in the cold periods of the Pleistocene. Smaller and larger landslides and rock falls are also characteristic of the steep slopes of solid rocks. On the Palaeogene and Neogene loose sediments of the hilly lands, as well as in the walls of the valleys of the extensive loess areas, various scales of large landslides (frequently several hundreds of metres), rotational slides and mudflows shaped the terrain. As a result of the rill erosion and surface erosion over a large area, on the lower section of the slopes deluvial sediments accumulated. Among the geological hazards still present today, the largest damage in Hungary is caused by slope movements. In recentdecades significant damage has been caused by the movements of the bluffs of Lake Balaton (e.g. Fonyód, Balatonkenese), and those of the Danube (e.g. Dunaföldvár, Dunaszekcső); furthermore, a similar type of damage has been caused bythe movement of the slopes of Hollóháza in the Zemplén Mountains. The age of the movements is Pleistocene to Holocene (including the present).

Drift sand (6Q)

In the dry periods of the Pleistocene and the Holocene, the erosional effects of wind processes were extremely high on the extensive Transdanubian surfaces of the sediments of Lake Pannon, and on those of the alluviation of rivers associated with the lake; these processes also affected the highly sandy terraces, alluvial fans and floodplains of the Quaternary rivers. Sand movements occurred in multiple phases and over large areas in the 19th and 20th centuries. The last, currently still more or less active dunes around Ágasegyháza are under protection. The largest wind-blown area is the Kiskunság, the sand material of which was transported here by NW winds. These winds broke into the Carpathian Mountains through the so-called Dévény Gate, between the Alps and the Carpathian Mountains. As a result of the NW winds, several smaller wind-blown areas were also formed in Transdanubia: on the terraces of the Danube, in the western foreland of the Transdanubian Range, and in the Belső-Somogy. The second largest wind-blown sand region is located in NE Hungary, in the Nyírség. As a result of the N-NE winds, on the surface of the alluvial fan of the rivers coming from the Carpathians and North Transylvania, in multiple phases intensive sand movements occurred during the Late Pleistocene and the Holocene (BORSY 1977). The movement of the sand was much more general on the area of Transdanubia during the Pleistocene and the Holocene, as proven by the abraded rock surfaces and also by the large amount of ventifacts; the latter are mostly known around the Transdanubian Range, the Börzsöny and the Cserhát (JÁMBOR 1992). More recently, their occurence has been pointed out in the southern foreland of the Mecsek as well — in fact, more frequently than previously thought (SEBE 2013).

HOLOCENE

Paludal sediments (5Q)

Paludal sediments occur in all regions of Hungary. Peat, clay of diverse organic material content, silty clay, and silt beds are found in Transdanubia on the floodplains of the Little Hungarian Plain, and on the Great Plain sections of the Danube, around Lake Fertő, in the so-called meridional valleys of the River Zala, and in the depressions of the south-eastern foreland of the Transdanubian Range (Vindornya Basin, Balaton area, Sárrét, Csíkvarsai-rét, and the Lake Velence area). In the North Hungarian Mountains only extremely small occurrences are known and these are not depicted on the map. On the area

of the Alföld (Great Hungarian Plain), paludal formations were deposited between the sand dunes of the Kiskunság — that is, on the floodplain area of the Solti-síkság (plain). In addition, large areas are also covered by the sediments of the one-time Ecsedi-láp (bog). The thickness of the paludal beds is several metres; the age is usually Holocene.

Lacustrine sediments (4Q)

Lacustrine sediments are dominantly made up of fine-grained sediments (clay, silt, silty sand) and calcareous mud. Characteristically, they occur in two environments. On the shores of large lakes, which were exposed to wind-induced wave action, sand bars were formed. The largest series of such sand bars are located between the Balaton and the Nagyberek. The largest uninterrupted occurrences are found around the three large lakes (Balaton, Lake Fertő and Lake Velence) of the Transdanubia. Other significant areas of lacustrine sediments on the Great Plain are the wind-blown sand areas of the Nyírség and the Kiskunság. In the depressions between the dunes, sediments of small lakes are frequently found. Lacustrine sediments have also been distinguished on the large floodplains. The thickness of the lacustrine succession is some decimetres, up to 10m (for example Balaton). The age of the lacustrine beds known on the surface is usually Holocene.

Fluvial sand, gravel (3Q)

Fluvial sand and gravel form most of today's river channels and the material of many valley floors. Locally, young gravel terraces have also formed. Young fluvial sediments occur over the entire area of Hungary; these occur in their most extensive form in the valleys of the Danube, the Tisza, the Rába, the Sajó and the Hernád. The thickness of the Holocene fluvial sediments varies significantly, ranging between thin valley floor fillings up until successions with a thickness of up to 10m.

Fluvial sediments (2Q)

The map depicts the mostly fine-grained (clay, silt, sand) formations of the youngest Holocene-recent floodplain and valley floor surfaces among the Holocene fluvial sediments.

Anthropogeneous banks, mine dump, slurry (1Q)

Underground and open-pit mining carried out in recent decades has resulted in the formation of many mine dumps in the mining areas of the Hungarian Mid-Mountains. These objects have changed the landscape. On a less-detailed map their depiction is on the one hand unnecessary, and on the other hand, due to their relatively small size, it cannot be easily achieved. Further difficulties arise from the fact that their patches on the map could cover (geologically) more important formations. For these reasons the map shows only two objects, indicating the existence of these anthropogenic features. These are the open-pit lignite mine of Bükkábrány and the open-pit mine dump of the Eocene brown coal of the Vértes. During the processing of the mining raw materials large-volume waste material may be formed. One notable example is the "red mud" — this is a by-product of bauxite processing, for the storage of which large mud reservoirs have been built. The map depicts one of these mud ponds — that of Almásfüzitő. Other anthropogenic fillings are not depicted, although on most parts of the inhabited areas several metres-thick artificial filling covers the original surface. At the same time, however, roads and railways shown on the map can be interpreted as fillings.

REFERENCES

BABINSZKI E., SZTANÓ O., MAGYARI Á., 2003: Epizodikus üledékképződés a Pannon-tó Kállai-öblében: A Kállai Homok nyomfosszíliái és szedimentológiai bélyegei. — *Földtani Közlöny* **133 (4),** pp. 363–382.

BÁLDI T. 1958: Adatok Budafok és Törökbálint környékének rétegtani viszonyaihoz. — *Földtani Közlöny* **88 (4),** pp. 428–436.

BÁLDI T. 1983: *Magyarországi oligocén és alsómiocén formációk.* — Akadémiai Kiadó, Budapest, pp. 109–116.

BÁLDI T. 1998: Magyarország epikontinentális oligocén képződményeinek rétegtana. — In: BÉRCZI I., JÁMBOR Á. (szerk): *Magyarország geológiai képződményeinek rétegtana.* — A MOL Rt. és a MÁFI kiadványa, pp. 419–435.

BÁLDINÉ BEKE M., BÁLDI T. 1990: A bakonyi eocén medence süllyedéstörténete. — *Általános Földtani Szemle* **25,** pp. 83–118.

BALLA Z. 1978: A Magas-Börzsönyi paleovulkán rekonstrukciója. — *Földtani Közlöny* **108 (1),** pp. 119–136.

BALLA Z., GYALOG L. (szerk.) 2009: A Mórágyi-rög északkeleti részének földtana. Magyarázó a Mórágyi-rög ÉK-i részének földtani térképsorozatához (1:10 000). — *Magyarország tájegységi térképsorozata.* A Magyar Állami Földtani Intézet kiadványa, Budapest.

BALOGH K., ÁRVA-SÓS E., PÉCSKAY Z., RAVASZ-BARANYAI L. 1986: K/Ar dating of post-Sarmatian alkali basaltic rocks in Hungary. — *Acta Mineralogica–Petrographica (Szeged),* **27 (1),** pp. 75–93.

BALOGH K., ERDÉLYI M., KRETZOI M., RÓNAI A., SCHRÉTER Z., SÜMEGHY J., SZEBÉNYI L., SZENTES F., SZŐTS E., URBANCSEK J. (szerk.) 1956: *Magyarország földtani térképe, 1:300 000.* — Magyar Állami Földtani Intézet kiadványa, Budapest.

BARABÁS A., BARABÁSNÉ STUHL Á. 1998: A Mecsek és környezete perm képződményeinek rétegtana. — In: BÉRCZI, I., JÁMBOR Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa pp. 187–215.

BARTHA F. 1971: A magyarországi pannon biosztratigráfiai vizsgálata. In: GÓCZÁN F., BENKŐ J. (szerk.): *A magyarországi pannonkori képződmények kutatásai.* — Akadémiai Kiadó, Budapest, pp. 9–172.

BENCE G., BERNHARDT B., BIHARI D., BÁLINT CS., CSÁSZÁR G., GYALOG L., HAAS J. ,HORVÁTH I., JÁMBOR Á., KAISER M., KÉRI J., KÓKAY J., KONDA J., LELKESNÉ FELVÁRI GY., MAJOROS GY., PEREGI ZS., RAINCSÁK GY., SOLTI G., TÓTH Á., TÓTH GY. 1990: A Bakony hegység földtani képződményei, Magyarázó a Bakony hegység fedetlen földtani térképéhez, 1: 50 000. — *A Magyar Állami Földtani Intézet alkalmi kiadványa,* Budapest 119 p.

BENDŐ ZS. 2001: Holdvilág-árok szelvényének rövid leírása. — *Kézirat,* Országos Földtani, Geofizikai és Bányászati Adattár.

BENEDEK, K. 2002: Paleogene igneous activity along the easternmost segment of the Periadriatic-Balaton Lineament. — *Acta Geologica Hungarica* **45 (4),** pp. 359–371.

BÉRCZI I., JÁMBOR Á (szerk.) BARABÁS A., BARANÁSNÉ STUHL Á., BÁLDI T., BÉRCZINÉ MAKK A., CSÁSZÁR G., DOSZTÁLY L., GULÁCSI Z., HAAS J., HÁMOR G., HIPS K., JUHÁSZ GY., KECSKEMÉTI T., KORPÁSNÉ HÓDI M., KOVÁCS S., LELKESNÉ FELVÁRI GY., MAJOROS GY., MÜLLER P., NAGYMAROSY A., NÉMEDI VARGA Z., RÁLISCHNÉ FELGENHAUER E., SZEDERKÉNYI T., TÖRÖK Á., VÖRÖS A. 1998: *Magyarország geológiai képződményeinek rétegtana.* — A MOL Rt. és a MÁFI kiadványa, Budapest, 517 p.

BÉRCZINÉ MAKK A., KONRÁD GY., RÁLISCHNÉ FELGENHAUER E., TÖRÖK Á. 2004: Tiszai egység. — In: HAAS J. (szerk.): *Magyarország geológiája. Triász.* Magyar Állami Földtani Intézet, Budapest, pp. 303–360.

BERNOR, R. L., FEIBEL, C., VIRANTA, V. 2003: The Vertebrate Locality of Hatvan, Late Miocene (Middle Turolian, MN12), Hungary. — In: PETCULESCU, A., STIUCA, E. (eds.): *Advances in Vertebrate Paleontology Hen to Panta.* — "Emit Racovii" Institute of Speleology, pp. 105–112.

BOHN–HAVAS, M., BÁLDI, T., KÓKAY, J., HALMAI, J. 1987: Pectinid assemblage zones of the Miocene in Hungary. — *Annales Instituti Geologici Publici Hungarici* **70,** pp. 441–446.

BORSY, Z. 1977: Evolution of relief forms in Hungarian wind-blown sand areas. — *Földrajzi Közlemények* **25 (101),** pp. 1–3.

BÖCKH J., KOCH A., PETHŐ GY., TELEGDI-RÓTH L., SCHAFARZIK F., SZONTAGH T. 1896: *Magyarország geologiai térképe 1:1 000 000* — A Magyarhoni Geologiai Társulat és a Magyar Királyi Geologiai Intézet kiadványa, Budapest.

BUDAI T., CSÁSZÁR G., CSILLAG G., DUDKO A., KOLOSZÁR L., MAJOROS GY. 1999: A Balaton-felvidék földtana. Magyarázó a Balaton-felvidék földtani térképéhez, 1:50 000. — *A Magyar Állami Földtani Intézet alkalmi kiadványa* **197,** 257 p.

BUDAI T., FODOR L. (szerk.), CSÁSZÁR G., CSILLAG G., GÁL N., KERCSMÁR ZS. KORDOS L., PÁLFALVI S., SELMECZI I. 2008: A Vértes hegység földtana. Magyarázó a Vértes hegység földtani térképéhez (1:50 000). — *Magyarország tájegységi térképsorozata.* A Magyar Állami Földtani Intézet kiadványa, Budapest, 368 p.

BUDAI T., GYALOG L. (szerk.), CHIKÁN G., CSILLAG G., HORVÁTH A., KERCSMÁR ZS., KOLOSZÁR L., KONRÁD GY., KORBÉLY B., KORDOS L., KOROKNAI B., KUTI L., PELIKÁN P., SELMECZI I. 2009: *Magyarország földtani atlasza országjáróknak 1:200 000.* — Magyar Állami Földtani Intézet, Budapest.

Császár G. (szerk.) 1996: *Magyarország litosztratigráfiai alapegységei. Kréta.* — A Magyar Állami Földtani Intézet kiadványa, Budapest.

Császár G. 1998a: A Dunántúli-középhegység alsó- és középső-kréta képződményeinek rétegtana. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 337–352.

Császár G. 1998b: A Mecsek és a Villányi-egység alsó- és középső-kréta képződményeinek rétegtana. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 353–369.

Császár G. (szerk.) 1997: *Basic Litostratigraphic Units of Hungary (Charts and short descriptions). Magyarország litosztratigráfiai alapegységei (Táblázatok és rövid leírások).* — A Magyar Állami Földtani Intézet kiadványa, Budapest, 114 p.

Csillag G. 1996: Diási Kavics Formáció. — In: Gyalog L. (szerk.): A földtani térképek jelkulcsa és a rétegtani egységek rövid leírása. — *Magyar Állami Földtani Intézet alkalmi kiadványa* **187,** p. 71.

Csillag G. 2008, Miocén-pliocén. — In: Budai T., Fodor L., (szerk.): *Magyarázó a Vértes hegység földtani térképéhez (1:50 000).* — Magyar Állami Földtani Intézet, Budapest, pp. 106–109.

Csillag G., Kordos L., Lantos Z., Magyar I. 2008: Felső-miocén. — In: Budai T., Fodor L., (szerk.): *Magyarázó a Vértes hegység földtani térképéhez (1:50 000).* — Magyar Állami Földtani Intézet, Budapest, pp. 93–106.

Csillag G., Sztanó O., Magyar I., Hámori Z. 2010: A Kállai Kavics települési helyzete a Tapolcai-medencében geoelektromos szelvények és fúrási adatok tükrében. — *Földtani Közlön*y **140 (2),** pp. 183–196.

Dosztály L., Gulácsi Z., Kovács S. 1998: Az észak-magyarországi jura képződmények rétegtana. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 309–318.

Dövényi Z. (szerk.) 2010: Magyarország kistájainak katasztere. — *MTA Földrajztudományi Kutatóintézet*, Budapest, 876 p.

Fodor L., Kázmér M., Magyari Á., Fogarasi A. 1992: Gravity-flow dominated sedimentation on the Buda paleoslope (Hungary). Record of Late Eocene continental escape of the Bakony Unit. ̶ *Geologische Rundschau* **82,** pp. 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,** pp. 129-305.

Főzy I. (szerk.) 2012: Magyarország litosztratigráfiai alapegységei. Jura. — *Magyarhoni Földtani Társulat kiadványa, Budapest,* 235 p.

Fülöp J. 1975: Tatai mezozóos alaphegységrögök. — *Geologica Hungarica series Geologica* **16,** 225 p.

Fülöp J. 1990: *Magyarország geológiája. Paleozoikum I.* — Magyar Állami Földtani Intézet kiadványa, 325 p.

Fülöp J. 1994: *Magyarország geológiája. Paleozoikum II.* — Akadémiai Kiadó, Budapest, 447 p.

Fülöp J., Rónai A., Hámor G., Nagy E., Császár G., Jámbor Á., Hetényi R., Deák M., Gyarmati P. 1984: Magyarország földtani térképe (Magyarország Földtani Atlasza), 1:500 000. — *Magyarország Földtani Térképei I.*, Magyar Állami Földtani Intézet, Budapest.

Gajdos I., Pap S. 1996: Nagyalföldi Tarkaagyag Formáció. — In: Gyalog L. (szerk.): A földtani térképek jelkulcsa és a rétegtani egységek rövid leírása. *Magyar Állami Földtani Intézet alkalmi kiadványa* **187**, Budapest, p. 69.

Gajdos I., Pap S., Somfai A., Völgyi L. 1983: Az alföldi pannóniai (s.l.) képződmények litosztratigráfiai egységei. — *A Magyar Állami Földtani Intézet alkalmi kiadványa.*

Grill J. 1988: A Rudabányai-hegység jura formációi — *A Magyar Állami Földtani Intézet Évi Jelentése az 1986. évről*, pp. 69–103.

Gyalog L., Ódor L. 1983: Felső-pannóniai bázisképződmények a Velencei-hegység keleti részén. — *A Magyar Állami Földtani Intézet Évi Jelentése 1981-ről*, pp. 413–423.

Gyalog L. (szerk.) 1996: A földtani térképek jelkulcsa és a rétegtani egységek rövid leírása. — *A Magyar Állami Földtani Intézet alkalmi kiadványa* **187,** Budapest, 172 p.

Gyalog L. (szerk.), Budai T., Chikán G., Ivancsics J., Kaiser M., Koroknai B., Kovács S., Maigut V., Palikán P., Síkhegyi F., Turczi G. 2005: Magyarázó Magyarország fedett földtani térképéhez (az egységek rövid leírása), 1:100 000. *A Magyar Állami Földtani Intézet térképmagyarázói.* — A Magyar Állami Földtani Intézet kiadványa, Budapest, 188 p.

Gyalog L., Budai T. (szerk.) 2004: Javaslatok Magyarország földtani képződményeinek litosztratigráfiai tagolására. — *A Magyar Állami Földtani Intézet Évi Jelentése 2002*, pp. 195–232.

Gyalog L., Budai T. (szerk.), Albert G., Gyarmati P., Kaiser M., Kuti L., Less Gy., Pelikán P., Scharek P., Síkhegyi F. 2009: Magyarország földtani térképe 1:200 000. — In: Budai T., Gyalog L. (szerk.): *Magyarország földtani atlasza országjáróknak 1:200 000.* — Magyar Állami Földtani Intézet, Budapest.

Gyalog L., Horváth I. (szerk.), Daridáné Tichy M., Dudko A., Ódor L, Budai T., Császár G., Cserny T., Csillag G., Kaiser M., Kókay J., Lelkesné Felvári Gy., Less Gy., Ó. Kovács L., Selmeczi I., T., Dobos V. 2004: A Velencei-hegység és a Balatonfő földtana. Magyarázó a Velencei-hegység földtani térképéhez (1:25 000) és a Balatonfő–Velencei-hegység mélyföldtani térképéhez (1:100 000). — *Magyarország Tájegységi Térképsorozata,* A Magyar Állami Földtani Intézet kiadványa, 316 p.

Gyalog L. 2013: *Magyarország földtani térképe.* — A Magyar Földtani és Geofizikai Intézet kiadványa, Budapest.

Haas J. (szerk.) 1993: *Magyarország litosztratigráfiai egységei. Triász.* — A Magyar Állami Földtani Intézet kiadványa, Budapest, 278 p.

Haas J. 1998a: A Dunántúli-középhegység felső-kréta képződményeinek rétegtana. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 371–378.

Haas J. 1998b: Az Alföld és Észak-Magyarország felső-kréta képződményeinek rétegtana. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 379–388.

Haas J. (szerk.) 2004: *Magyarország geológiája.* — ELTE Eötvös kiadó, Budapest, 384 p.

Haas J., Budai T. 2004: Dunántúli-középhegységi egység. — In: Haas J. (szerk.): *Magyarország geológiája. Triász.* Magyar Állami Földtani Intézet, Budapest, pp. 25–124.

Hably, L. 2013: The Late Miocene Flora of Hungary. — *Geologica Hungarica series Palaeontologica* **59,** 175 p.

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Hajós M. 1971: A csákvári neogén medence alsópannóniai diatomás rétegeinek mikroflórája. — *A Magyar Állami Földtani Intézet Évi Jelentése 1968. évről*, pp. 33–40.

Halaváts G. 1923: A baltavári felsőpontusi korú molluszka fauna. — *A Magyar Királyi Földtani Intézet Évkönyve* **24 (6),** pp. 395–407.

Hámor G. 1970: A kelet-mecseki miocén. — *A Magyar Állami Földtani Intézet Évkönyve* **53 (1),** 484 p.

Hámor G. 1985: A nógrád-cserháti kutatási terület földtani viszonyai. — *Geologica Hungarica series Geologica* **22,** 307 p.

Hámor G. 1998: A magyarországi miocén rétegtana. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 437–452.

Harangi, Sz., Wilson, M., Tonarini, S. 1995: Petrogenesis of Neogene potassic volcanic rocks in the Pannonian Basin. — In: Downes H., Vaselli, O. (eds): Neogene and related magmatism in the Carpatho-Pannonian Region. — *Acta Vulcanologica* **7,** pp. 125–134.

Hauer, F. R. 1871: *Geologische übersichts-karte der Österreichisch–Ungarischen Monarchie.* — K. K. Geologischen Reichanstalt, Wien.

Horváth E., Bradák B. 2014: Sárga föld, lősz, lösz: Short historical overview of loess research and lithostratigraphy in Hungary. — *Quaternary International* **319,** pp. 1-10.

Horváth, E. 2001: Marker horizons in the loesses of the Carpathian Basin. — *Quaternary International* **76–77,** pp. 157–163.

Horváth I., Daridáné Tichy M., Ódor L. 1983: Magnezittartalmú dolomitos karbonatit (beforsit) telérkőzet a Velencei-hegységből. — *A Magyar Állami Földtani Intézet Évi Jelentése az 1981. évről*, pp. 369–388.

Jámbor Á 1996: Pulai Alginit Formáció. — In: Gyalog L. (szerk.): A földtani térképek jelkulcsa és a rétegtani egységek rövid leírása. *A Magyar Állami Földtani Intézet Alkalmi Kiadványa* **187,** p. 71.

Jámbor Á., Radócz Gy. 1970: Pectinariák a Magyarország felsőneogénjéből. — *Földtani Közlöny* **100 (3),** pp. 360–371.

Jámbor Á. (szerk.) 1981: Földtani kirándulások a magyarországi molassz területeken, 14. megálló, Hosszúpereszteg, homokbánya (felső-pannóniai). — *A Magyar Állami Földtani Intézet alkalmi kiadványa*, p. 102.

Jámbor Á. 1971: Alsópannóniai diatomaföld-rétegek a csákvári neogén medencében.— *A Magyar Állam Földtani Intézet Évi Jelentése 1968. évről*, pp. 26–31.

Jámbor Á. 1980: A Dunántúli-középhegység pannóniai képződményei. — *A Magyar Állami Földtani Intézet Évkönyve* **62,** 259 p.

Jámbor Á. 1990: Miocén–pliocén, A Bakony hegység földtani képzdményei. *Magyarázó a Bakony hegység fedetlen földtani térképéhez 1:50 000.* — *Magyar Állami Földtani Intézet kiadványa*, pp. 59–66.

Jámbor Á. 1996a: Kisbéri Kavics Formáció. — In: Gyalog L. (szerk.): A földtani térképek jelkulcsa és a rétegtani egységek rövid leírása. *A Magyar Állami Földtani Intézet alkalmi kiadványa* **187,** p. 74.

Jámbor Á. 1996b: Somlói Formáció. — In: Gyalog L. (szerk.): A földtani térképek jelkulcsa és a rétegtani egységek rövid leírása. *A Magyar Állami Földtani Intézet alkalmi kiadványa* **187,** p. 71.

Jámbor Á. 1996c: Toronyi Formáció. — In: Gyalog L. (szerk.): A földtani térképek jelkulcsa és a rétegtani egységek rövid leírása. *A Magyar Állami Földtani Intézet alkalmi kiadványa* **187,** p. 70.

Jámbor Á. 1998: A Tiszai Nagyszerkezeti Egység karbon képződményei rétegtanának ismertetése. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 173–185.

Jámbor, Á. 1992, Pleistocene ventifact occurrences in Hungary. — *Acta Geologica Hungarica* **35 (4),** pp. 407–436.

Jaskó S., Kordos L. 1990: A Budapest–Adony–Örkény közötti terület kavics formációja. — *A Magyar Állami Földtani Intézet Évi Jelentése az 1988. évről*, pp. 153–167.

Juhász, E., Müller, P., Tóth-Makk, Á., Hámor, T., Farkas-Bulla, J., Phillips, J. D., Sütő-Szentai, M.,, Ricketts, B. 1996: High-resolution sedimentological, subsidence analysis of the Late Neogene, Pannonian Basin, Hungary. — *Acta Geologica Hungarica* **39 (2),** pp. 129–152.

Juhász Gy. 1994: Magyarországi neogén medencerészek pannóniai s.l. üledéksorának összehasonlító elemzése. — *Földtani Közlöny* **124 (3),** pp. 341–365.

Kaiser M., Gyalog L. 2005: A negyedidőszaki képződmények genetikai típusok szerinti leírása. — In: Gyalog L. (szerk.): *Magyarázó Magyarország fedett földtani térképéhez (az egységek rövid leírása).* Magyar Állami Földtani Intézet, Budapest, pp. 142–148.

Kaiser, T. M., Bernor, R. L. 2006: The Baltavar Hippotherium. A mixed feeding Upper Miocene hipparion (Equidae, Perissodactyla) from Hungary (East-Central Europe). — *Beiträge zur Paläontologie* **30,** pp. 241–267.

Kecskeméti T. 1980: A Bakony-hegységi Nummulites-fauna paleobiogegoráfiai áttekintése. — *Földtani Közlöny* **110,** pp. 432–449.

Kecskeméti T. 1993: Paleokommunitás vizsgálatok a Bakony eocén nagyforaminiferáin. — *Őslénytani Viták* **39,** pp. 97–115.

Kecskemétiné Körmendy A. 1963: Biosztratigráfiai vizsgálatok a Dorogi-medence eocén korú molluszkumos képződményein. — *Földtani Közlöny* **93 (4),** pp. 451–464.

Kecskemétiné Körmendy A. 1966: A Dorog környéki eocén biofácies-vizsgálata. — *A Magyar Állami Földtani Intézet Évi Jelentése az 1964-es évről*, pp. 329–337.

Kele S. 2009: Édesvízi mészkövek vizsgálata a Kárpát-medencéből. Paleoklimatológiai és szedimentológiai elemzések. — *PhD thesis,* Eötvös Loránd Tudományegyetem Természettudományi Kar, Budapest 176 p.

Kele S., Scheuer G., Demény A., Shen C. C., Chiang, H. V. 2011: A Rózsadomb (Budapest) édesvízi mészköveinek U/Th sorozatos kormeghatározása és stabilizotóp-geokémiai vizsgálata. — *Földtani Közlöny* **141 (2),** pp. 445–468.

Kercsmár, Zs., Fodor, L. 2005: Syn-sedimentary deformations in the Eocene Tatabanya Basin, Central Hungary. — *Geolines* **19**, *3rd Meeting of the Central European Tectonics Studies Group, Felsőtárkány, Hungary, April 14–17, 2005*, pp. 60–61.

Kercsmár Zs. 2005: Középső-eocén karbonátos üledékképződési környezetek és egymásra épülésük a Tatabányai-medence DK-i peremén. — *A Magyar Állami Földtani Intézet Évi Jelentése 2004*, pp. 215–235.

Kercsmár Zs. 2010: A É-i Gerecse eocén rétegsora a legújabb kutatások tükrében. — *EMT 12. Bányászati-Kohászati és Földtani Konferencia kiadványa*, Nagyenyed 2010. április 8–11. pp. 148–153.

KERCSMÁR ZS., BUDAI T., CSILLAG G., SELMECZI I., LANTOS Z., BABINSZKI E., MAROS GY. 2014: A klasszikus földtani térképezés gazdasági, társadalmi és tudományos jelentősége. — *MFGI Évi Jelentése 2012–2013-ról,* pp. 167–178.

KISHÁZI P., IVANCSICS J. 1975: A brennbergi barnakőszén-medence földtani-teleptani viszonyainak posztumusz rekonstrukciója. — *Bányászati és Kohászati Lapok, Bányászat* **108** (különszám), pp. 128–131.

KLEB B. 1973: A mecseki pannon földtana. — *A Magyar Állami Földtani Intézet Évkönyve* **53 (3),** pp. 751–923.

KÓKAY J. 1972: Az ottnangien faciosztratotípus szelvényei a Várpalotai-medencében. — *Földtani Közlöny* **102,** pp. 40–53.

KÓKAY, J. 1973: Faziostratotypen der Bántapusztaer Schichtengruppe. — In: PAPP, A., RÖGL, F., SENEŠ, J. (eds): M2 Ottnangien, Chronostratigraphie und Neostratotypen, III., Bratislava, p. 126.

KÓKAY J. 1987: A várpalotai bádeni képződmények rétegtani tagolása és ősföldrajzi rekonstrukciója. — *A Magyar Állami Földtani Intézet Évi Jelentése 1985-ről,* pp. 235–241.

KÓKAY J. 1988: Bakony, Várpalota, Szabó-féle homokbánya. — *Magyarország Geológiai Alapszelvényei* **108,** A Magyar Állami Földtani Intézet kiadványa.

KÓKAY J. 1990: A budapesti középső-bádeni képződmények. — *A Magyar Állami Földtani Intézet Évi Jelentése 1988-ról,* pp. 101–108.

KÓKAY, J. 1998: Dunántúli bádeni szelvények összehasonlító rétegtani elemzése és az eusztatikus tengerszint ingadozások. — *Földtani Közlöny* **126,** pp. 97–115.

KÓKAY, J. 2006: Nonmarine mollusc fauna from the Lower and Middle Miocene, Bakony Mts, W Hungary. — *Geologica Hungarica series Palaeontologica* **56,** 196 p.

KÓKAY J., HÁMOR T., LANTOS M., MÜLLER P. 1991: A Berhida 3. sz. fúrás paleomágneses és földtani vizsgálata. — *A Magyar Állami Földtani Intézet Évi Jelentése az 1989. évről,* pp. 45–63.

KOLOSZÁR, L., MARSI, I., 2010: The thickest and the most complete loess sequence in the Carpathian basin: the borehole Udvari–2A. — *Central European Journal of Geosciences* **2 (2),** pp. 165–174.

KOPEK G., KECSKEMÉTI T., DUDICH E. 1965: A Dunántúli-középhegység eocénjének rétegtani kérdései. — *A Magyar Állami Földtani Intézet Évi Jelentése az 1964. évről,* pp. 249–263.

KORPÁS L. (szerk.) 1998: Magyarázó a Börzsöny és a Visegrádi-hegység földtani térképéhez. *A Magyar Állami Földtani Intézet Térképmagyarázói.* — A Magyar Állami Földtani Intézet kiadványa, Budapest, 216 p.

KORPÁS L. 1981: A Dunántúli-középhegység oligocén–alsó-miocén képződményei. — *A Magyar Állami Földtani Intézet Évkönyve* **64,** 140 p.

KOVÁCS S. 1998: A Szendrői és Upponyi-hegység paleozoós képződményeinek rétegtana. — In: BÉRCZI I., JÁMBOR Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 107–117.

KOVÁCS S., LESS GY., HIPS K., PIROS O., JÓZSA S. 2004: Aggteleki–rudabányai egységek. — In: HAAS J. (szerk.): *Magyarország geológiája. Triász.* Magyar Állami Földtani Intézet, Budapest, pp. 197–288.

KOVÁCS S., LESS GY., PIROS O., RÓTH L. 1988: Az Aggtelek–Rudabányai-hegység triász formációi. — *A Magyar Állami Földtani Intézet Évi Jelentése 1986-ról,* pp. 19–43.

KROLOPP E. 1978: A szabadhídvégi alsópleisztocén fauna. — *A Magyar Állami Földtani Intézet Évi Jelentése 1976-ról,* pp. 297–310.

KUBOVICS I., SZABÓ CS. 1988: Az Alcsútdoboz 2. sz. fúrás alkáli bázisos, ultrabázisos telérkőzeteinek ásvány-kőzettani és geokémiai vizsgálata. — *A Magyar Állami Földtani Intézet Évkönyve* **95 (2),** pp. 335–356.

LELKESNÉ FELVÁRI GY. 1998: A Dunántúli-középhegység metamorf képződményeinek rétegtana. — In: BÉRCZI I., JÁMBOR Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 73–86.

LESS, GY. 1987: Paleontology and stratigraphy of the European Orthophragminae. — *Geologica Hungarica series Palaeontologica* **50,** pp. 1–373.

LESS, GY., BÁLDI-BEKE, M., PÁLFALVI, S., FÖLDESSY, J., KERTÉSZ, B. 2008: New data on the age of the Recsk volcanics and of the adjacent sedimentary rocks. — *Publications of the University of Miskolc; Series A — Mining* **73,** pp. 57–84.

LÓCZY L., PAPP K. (szerk.) 1922: A Magyar Birodalom és a szomszédos országok határos területeinek földtani térképe (1:900 000). — *Magyar Királyi Földtani Intézet Kiadványa.*

LYELL, C. 1830. *Principles of geology, being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation.* — Handbook, John Murray, London.

MAGYAR, I., SZTANÓ, O. 2008: Is there a Messinian unconformity in the Central Paratethys? — *Stratigraphy* **5** (3–4), pp. 245–255.

MAGYAR, I. 1988: Mollusc fauna and flora of the Pannonian quartz sandstone at Mindszentkálla, Hungary. — *Annales Scientiarum Budapestinensis de Rolando Eötvös Nominatae Sectio Geologica* **28,** pp. 209–222.

MAGYAR, I. 1992: An upper Pannonian s. l. (Miocene) mollusc fauna from Fehérvárcsurgó (Hungary). — *Annales Scientiarum Budapestinensis de Rolando Eötvös Nominatae, Sectio Geologica* **29,** pp. 285–302.

MAGYAR, I., LANTOS, M., UJSZÁSZI, K., KORDOS, L. 2007: Magnetostratigraphic, seismic and biostratigraphic correlations of the Upper Miocene sediments in the northwestern Pannonian Basin System. — *Geologica Carpathica* **58 (3),** pp. 277–290.

MAGYAR, I., MÜLLER, P., GEARY, D. H., SANDERS, H. C., TARI, G. C. 2000: Diachronous deposits of Lake Pannon in the Kisalföld basin reflect basin and mollusc evolution. — *Abhandlungen der Geologischen Bundesanstalt* **56,** pp. 669–678.

MAGYAR, I. 2010: *A Pannon-medence ősföldrajza és környezeti viszonyai a késő miocénben.* — Geolitera, Szeged, 140 p.

MAGYAR, I. 2013: Geological background. — In: HABLY, L. 2013: *The Late Miocene Flora of Hungary.* — *Geologica Hungarica series Palaeontologica* **59,** pp. 10–14.

MAJOROS GY. 1998: A Dunántúli-középhegység újpaleozoós képződményeinek rétegtana. — In: BÉRCZI I., JÁMBOR Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 119–147.

MARTIN, U., NÉMETH, K. 2004: Mio/Pliocene Phreatomagmatic Volcanism in the Western Pannonian Basin. — *Geologica Hungarica Series Geologica* **26,** 191 p.

MINDSZENTY A., CSOMA A., TÖRÖK Á., HIPS K., HERTELENDI E. 2000: Flexura jellegű előtéri deformációhoz köthető karsztbauxitszintek a Dunántúli-középhegységben. — *Földtani Közlöny* **131 (1–2),** pp. 107–152.

MOTTL M. 1939: A gödöllői vasúti bevágás középső pliocénkori faunája. — *A Magyar Állam Földtani Intézet Évkönyve* **32 (3),** pp. 255–350.

MÜLLER P., MAGYAR I. 2008: A budai pannóniai képződmények. — *Földtani Közlöny* **138 (4),** pp. 345–356.

MÜLLER P., SZÓNOKY M. 1988: Tihanyi-félsziget, Tihany, Fehér-part. — *Magyarország Geológiai Alapszelvényei, Magyar Állami Földtani Intézet kiadványa*, 4 p.

NAGY L.-NÉ 1969: A Mecsek hegység miocén rétegeinek palynológiai vizsgálata. — *A Magyar Állami Földtani Intézet Évkönyve* **52 (2),** 649 p.

NAGYMAROSY, A., BÁLDI-BEKE, M. 1988: The position of the Paleogene formations of Hungary in the standard nannoplankton zonation. — *Annales Universitatis Scientiarium Budapestinensis de Rolando Eötvös, Nominatae, Sectio Geologica* **28,** pp. 3–25.

NAGYMAROSY, A. 1985: The correlation of the Badenian in Hungary based on nannofloras. — *Annales Universitatis Scientiarium Budapestinensis de Rolando Eötvös Nominatae, Sectio Geologica* **25,** pp. 33–86.

NÉMEDI VARGA Z. 1998: A Mecsek és a Villányi egység jura képződményeinek rétegtana. — — In: BÉRCZI I., JÁMBOR Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 319–336.

NÉMETH, K., MARTIN U., CSILLAG G. 2003: Lepusztult freatomagmás vulkáni kráter- és kürtőkitöltés-roncsok (diatrémák) a Bakony–Balaton-felvidék vulkáni területen. — *A Magyar Állami Földtani Intézet Évi Jelentése, 2000–2001*, pp. 83–99.

PÁLFY, J., MUNDIL, R., RENNE, P. R., BERNOR, R. L., KORDOS, L., GASPARIK, M. 2007: U–Pb and ^{40}Ar/^{39}Ar dating of the Miocene fossil track site at Ipolytarnóc (Hungary) and its implications. — *Earth and Planetary Science Letters* **258,** pp. 160–174.

PASCHER, G. 1991: Das Neogen der Mattersburger Bucht (Burgenland). — In: LOBITZER, H., CSÁSZÁR, G. (eds): *Jubiläumsschrift 20 Jahre Geologische Zusammenarbeit Österreich–Ungarn Teil 1.*, Wien, pp. 35–52.

PÉCSI M. 1993: *Negyedkor és löszkutatás.* — Akadémiai Kiadó, Budapest, 376 p.

PELIKÁN P., BUDAI T. (szerk.), LESS GY., KOVÁCS S., PENTELÉNYI L., SÁSDI L. 2005: A Bükk hegység földtana. Magyarázó a Bükk hegység földtani térképéhez (1:50 000). *Magyarország Tájegységi Térképsorozata.* — A Magyar Állami Földtani Intézet kiadványa, 284 p.

PEREGI ZS. 1996: Borsodi Kavics Formáció. — In: GYALOG L. (szerk.): A földtani térképek jelkulcsa és a rétegtani egységek rövid leírása. *A Magyar Állami Földtani Intézet alkalmi kiadványa* **187,** p. 72.

RADÓCZ GY. 1978: Felsőnyárád (Felsőnyárádi Formáció). — *Lexique Stratigraphique International I., Europe, 9. Hongrie, Centre National de la Recherche Scientifique, Paris*, 2, pp. 206–207.

RÖGL, F. 1998: Palaeogeographic consideration for Mediterranean and Paratethys seaways (Oligocene to Miocene). — *Annalen des Naturhistorischen Museums in Wien* **99,** A, pp. 279–310.

RÖGL, F., ĆORIĆ, S., HARZHAUSER, M., JIMENEZ-MORENO, G., KROH, A., SCHULTZ, O., WESSELY, G., ZORN, I. 2008: The Middle Miocene Badenian stratotype at Baden-Sooss (Lower Austria). — *Geologica Carpathica* **59 (5),** pp. 367–374.

SEBE, K. 2013: Ventifacts in the Mecsek region (SW Hungary) — climatic interpretation and tectonic implications. — *Zeitschrift für Geomorphologie* **57 (3),** pp. 305–323.

SEBE K., MAGYAR I., CSILLAG G., SZTANÓ O. 2015: A mecseki pannóniai üledékek rétegtana: új adatok, eredmények és kérdések.— In*:* DÁLYAY V., SÁMSON M. (szerk.): *Tisia Konferencia, Magyarhoni Földtani Társulat, Pécs, 2015,* pp. 72–76.

SELMECZI I., FODOR L. 2008: Mányi Formáció. — In: BUDAI T., FODOR L. (szerk.): A Vértes hegység földtana. Magyarázó a Vértes hegység földtani térképéhez (1 50 000) *Magyarország Tájegységei Térképsorozata.* — A Magyar Állami Földtani Intézet kiadványa, pp. 85–86.

SÜMEGHY B., KISS T., SIPOS GY., TÓTH O. 2013: A Maros hordalékkúp felső-pleisztocén-holocén fluviális képződményei. — *Földtani Közlöny* **143 (3),** pp. 265–278.

SÜTŐ-SZENTAI M., SELMECZI I. 2004: Felszíni alsópannóniai előfordulás Felcsúton. Szervesvázú mikroplankton és sporomorpha maradványok. — *Folia Musei Historico-Naturalis Bakonyiensis* **20,** pp. 47–62.

SÜTŐNÉ SZENTAI M. 1991: Szervesvázú mikroplankton zónák Magyarország pannóniai rétegösszletében. Újabb adatok a zonációról és a dinoflagelláták evolúciójáról: *Őslénytani Viták* **36–37,** pp. 157–200.

SZENTPÉTERY I., LESS GY. (szerk.) 2006: Az Aggtelek–Rudabányai-hegység földtana, *Magyarország tájegységi térképsorozata. Magyarázó az Aggtelek–Rudabányai hegység 1988-ban megjelent 1:25 000 méretarányú fedetlen földtani térképéhez.* — A Magyar Állami Földtani Intézet kiadványa, Budapest, 92 p.

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),** pp. 267–290.

SZTANÓ, O. 1994: The tide-influenced Pétervására Sandstone, early Miocene, northern Hungary: sedimentology, palaeogeography and basin development. — *PhD thesis, Geologica Ultraiectina* **120,** 155 p.

SZTANÓ O., MAGYARI Á., NAGYMAROSY A. 1998: Az Esztergomi-medence oligocén képződményeinek integrált sztratigráfiai vizsgálata. II. Oligocén szekvenciák és értelmezésük. — *Földtani Közlöny* **128 (2–3),** pp. 455–486.

SZTANÓ O., MAGYAR I., SZÓNOKY M., LANTOS M., MÜLLER P., LENKEY L., KATONA L., CSILLAG G. 2013: A Tihanyi Formáció a Balaton környékén: típusszelvény, képződési körülmények, rétegtani jellemzés.— *Földtani Közlöny* **143 (1),** pp. 73–98.

SZTANÓ O., MAGYARI A., TÓTH P. 2010: Gilbert-típusú delta a pannóniai Kállai Kavics Tapolca környéki előfordulásaiban. — *Földtani Közlöny* **140 (2),** pp. 167–182.

THAMÓ-BOZSÓ E., CSILLAG G., FODOR L., MÜLLER P., NAGY A. 2010: OSL-dating the Quaternary landscape evolution in the Vértes Hills forelands (Hungary). — *Quaternary Geochronology* **5 (2–3),** pp. 120–124.

TÓTH K. (2014): A diszeli bauxit. — *Földtani Közlöny* **144 (4),** pp. 315–328.

TÓTH K. 1971: A Vértes hegység délkeleti előterének pannon képződményei. — In: GÓCZÁN F., BENKŐ J. (szerk.): *A magyarországi pannonkori képződmények kutatásai.* Akadémiai Kiadó, Budapest, pp. 345–361.

Tóth P. Szafián P., Sztanó O. 2010: Egy pannóniai korú Gilbert-delta felépítése "3D" földradar (GPR) szelvények alapján. — *Földtani Közlöny* **140 (3),** pp. 235–249.

Török Á. 1998: A Mecsek-Villányi Egység triász képződményeinek rétegtana. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 253–280.

Uhrin, A., Sztanó, O. 2007: Reconstruction of Pliocene fluvial channels feeding Lake Pannon (Gödöllő Hills, Hungary). — *Geologica Carpathica* **58 (3),** pp. 291–300.

Uhrin A., Sztanó O., Csillag G., Hámori Z. 2011: Késő-miocén–pliocén folyók rekonstrukciója a Vértes délkeleti előterében. — *Földtani Közlöny* **141 (4),** pp. 363–381.

Varga Gy., Csillagné Teplánszky E., Félegyházi Zs. 1975: A Mátra hegység földtana. — *A Magyar Állami Földtani Intézet Évkönyve* **57 (1),** 575 p.

Velledits F., Pelikán P., Hips K., Harangi Sz., Haas J., Józsa S., Kovács S. 2004: Bükki egység. — In: Haas J. (szerk.): *Magyarország geológiája. Triász.* A Magyar Állami Földtani Intézet kiadványa, Budapest, pp. 139–196.

Vörös A. 1998: A Dunántúli-középhegység jura képződményeinek rétegtana. — In: Bérczi I., Jámbor Á. (szerk.): *Magyarország geológiai képződményeinek rétegtana.* A MOL Rt. és a MÁFI kiadványa, Budapest, pp. 299–308.

Zelenka T. 2010: A Mátra hegység paleogén és neogén vulkanizmusa. — In: Baráz Cs. (szerk.): A *Mátrai Tájvédelmi Körzet. Heves és Nógrád határán.* Bükki Nemzeti Parki Igazgatóság, Eger, pp. 27–38.

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