JAHRBUCH DER GEOLOGISCHEN BUNDESANSTALT
Jb. Geol. B.-A. | ISSN 0016-7800 | Band 142 | Heft 4 | S. 421–445 | Wien, Dezember 2000
Danube Region Environmental Geology Programme DANREG — Explanatory Notes | Editor: G. Császár

Surface Geological Map

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Introduction

The surface geological map is a source map for the rest maps of the DANREG programme. Its compilation was preceded by a careful preparation of a common legend. This process was hampered by the fact that the scales of mapping were different not only by countries but also by areas within each country. The DANREG programme includes several map varieties. Some of these, especially the Tectonic and the Pre-Tertiary basement maps provide us with an opportunity to introduce the structural units and elements. Therefore the aim of the present explanatory notes is to briefly introduce the formations occurring on the surface. The explanatory notes reflect the differences in geological setting of the larger tectonic (geographic) units. The description will be given by tectonic units in the Alpine–Carpathian belts, by larger chronostratigraphic units in the Transdanubian Range, and only the Quaternary sediments are to be shown in the Little Hungarian Plain (Kisalföld) and Danube Lowland areas.

The Austrian portion of the DANREG area contains the SW–NE striking Alpine–Carpathian Mountain range in its centre, separating the Vienna Basin in the NW from the Little Hungarian Plain in the southeastern region. From the latter, the Eisenstädter Basin in the western part, W of the Lake Neusiedl/Fertõ, which is closely connected to the Vienna Basin itself, is separated by the heights of the Ruster Höhenzug and the Sopron Hills.

The geological map of the Slovak side represents the first uniformly compiled map in the scale 1:100 000 from the whole area of the Danube Lowland (PRISTAπ, ELEÈKO, KONEÈN″, VASS, VOZÁR in TKÁÈOVÁ *et al.* 1996). The results of new geophysical measurements were also used as well as the field check of a large part of the area studied. The newly mapped territories are as follows: Southern part of the Trnava and Nitra hilly lands, the left-side area of the Little Danube River, the confluence area of the Váh and Little Danube (Váh-derived Danube) rivers, and neovolcanics of the Ipel' Hilly Land and Kováèovské kopce Hills (Burda).

The Hungarian part of the DANREG area morphologically can be divided into the following three major regions: the Sopron Hills, the Transdanubian Range and the Little Hungarian Plain. This division, however, shows the structure of the area only in part and mainly reflects its configuration determined by the latest tectonic movements.

The differences occurring in the distribution of the surface formations are reflected rather well in the basic morphological units mentioned above. The core of the Sopron Hills is consists by Central Alpine–Little Carpathians (Tatric) crystalline rocks. Among their outcrops there are also some basins filled up by Miocene sediments. The Kisalföld is characterised by thick Quaternary and even thicker Neogene clastic formations. In the Transdanubian Range the sequences from the Triassic up to the top of the Oligocene are present in equal proportions. The occurrence of the Miocene and Pannonian formations can be prominent on the margins or in the inner basins.The the north-eastern part of the region (*i.e.* the Visegrád and Börzsöny Mountains) is determined by the Miocene volcanic products.

Alpine–Carpathian belt

Central Alpine Unit, Tatricum

Pre-Tertiary units

CRYSTALLINE FORMATIONS

The Leitha Hills forms the northeasternmost spur of the Central Alpine chain. Lithologically it closely resembles the Lower Austroalpine Unit of the Semmering–Wechsel area and therefore it is assumed that they belong into the same tectonic unit. As far as exposed at all, the main part is built up by micaschists, locally altering into schistose paragneisses and quartzitic layers, with rare small intercalations of amphibolites. The micaschists contain, besides quartz, usually prevalently white mica, some biotite, relics of garnet and sometimes of staurolite. Feldspar (plagioclase) is mostly present (at least some grains), sometimes so enriched that gneissic rock types occur. All rocks exhibit more phyllitic/phyllonitic features due to diaphthoresis. Therefore chlorite, replacing biotite, garnet and hornblende (in amphibolites) is wide-spread.

The exposures of basement rocks in the Rust Range and in the Sopron Hills show a similar composition and development, but in the Ruster area paragneisses, rich in biotite, are predominant.

In all basement rocks mentioned above occur **Grobgneiss** bodies. This is usually a coarse-grained gneiss of granitic origin, consisting of microcline feldspar, plagioclase, quartz, biotite and white mica with accessory garnet, epidote, zircon and apatite. It occurs in the western part of the Leitha Hills, in the Sopron Hills and in the Rust Range west of Mörbisch as well as in its northern part.

These crystalline islands, surrounded by Tertiary and Quaternary sediments, are clearly the continuation of the Semmering–Wechsel system towards southwest and belonging to the Lower Austroalpine nappe complex. In comparison with the less weathered and better exposed areas it can be said that the originally probably Palaeozoic sediments were altered in Hercynian times by an at least medium-grade metamorphosis. According to the occurrence of Grobgneiss in all parts the tectonic position seems to be equivalent to the higher nappe complex, *i.e.* the Grobgneiss Unit, of the Lower Austroalpine system.

The easternmost crystalline area, the Hainburger Hills, are somewhat different from the ones mentioned before. Consisting of a granodiorite core with abundant pegmatitic and aplitic veins, covered by a series of paragneisses and micaschist with garnet and staurolite, followed by lower grade biotite-rich phyllites, quartzitic schists and greenschists, these rocks lack the strong alpidic overprint (like the Lower Austroalpine). Therefore they are regarded rather to be part of the Malé Karpaty Mts. For the present, the correlation with the proper Alpine units is still unclear and matter of discussion, like the interpretation given by TOLLMANN (1987) as part of the central Penninic ridge.

The Tatricum is the northeastern continuation of the Central Alpine Unit on Slovak territory. This lowermost tectonic unit occurs in this map only in the Malé Karpaty Mts. The Tatricum (ANDRUSOV *et al.* 1973) represents hereby the unit correlated with the Lower Austro-Alpine units (Unterostalpinikum, *cfr*. TOLLMANN 1971, 1987) M. MAHEL' (1986) described the Tatricum in the frame of the Malé Karpaty Mts as the most externally located zone of this tectonic unit with specific features of geological and tectonic development. These are: the unusual development of the crystalline basement, the presence of the Early Palaeozoic metasediments and metavolcanites as well as the cover in four sequences. Besides the Malé Karpaty Mts and neighbouring pre-Tertiary basement, the Tartricum is allocated in the map of pre-Tertiary basement in the area of southern continuation of the PovaΩsk˝ Inovec and Tribeè Mts, also. Crystalline basement and cover are undistinguished and the Tatricum is defined as the PovaΩsk˝ Inovec and the Tríbeè groups.

In the Malé Karpaty Mts the Tatricum is represented by crystalline rocks and cover sequences, well-preserved mainly near the western margin of the mountains.

The crystalline basement comprises metamorphic complexes of Devonian to Early Carboniferous age, determined with the help of sporomorphs, crinoidal remnants and acritarcha (ÈORNÁ 1968, PLANDEROVÁ 1984). According to other sources, the stratigraphic span of metamorphic complexes is early Late Silurian. The upper age boundary of the statigraphic span is limited by the radiometric age of granitoids (380–350 Ma; CAMBEL 1980), with contact metamorphism of their cover.

In the geological map, the following metamorphic sequences have been distinguished in two areas: the Pezinok–Pernek crystalline and the Harmónia succession. The various dominant metamorphic sediments of the range Silurian–Devonian are: phyllites, mica-bearing schists, metamorphites of the biotite-garnet zone, chlorite-biotite phyllites, metasandstones and metagreywackes, metasandstones, mica schists and paragneisses. In the Devonian age dark and graphitic schists, metaquartzites and green schists are distinguished, mainly in the succession near Marianka and Harmónia localities. The distinctive group presents indications of contact metamorphism of biotite–garnet isograde and spotted shale (schists), prevailing in the Harmónia succession. Locally there are individual bodies of basic rocks, metabasites and amphibolites.

Abyssal magmatites present two bodies in tectonic nappe relation (MAHEL' 1986). Petrographically these represent two types of granitoids (CAMBEL 1980). The Modra Granodiorite Massif is mainly biotitic, rarely two-mica, has more basic character and relatively less pegmatite. Granitoids of the Bratislava Massif are relatively more acidic represented by muscovite–biotite granodiorite–monzonite. In our geological map 1:100 000 based on the cited works, mainly the Geological map of Malé Karpaty Mts [MAHEL' (ed.) 1972] and Geological map of Velká Bratislava 1:25 000 (VASKOVSKY *et al.*1988), in the Bratislava Massif have been distinguished fine-grained biotitic and two-mica granites, granodiorites; medium-grained leucocratic muscovitic and two-mica granites, granodiorites; coarse-grained muscovitic and muscovitic-biotitic granites, granodiorites rich in pegmatites, next aplites and pegmatites as individual dykes and the final diorite bodies.

The Central Alpine crystalline basement crops out alsoo in the Sopron Hills, in the southern continuation of the Rust Range. Although considerable efforts have been dedicated to the research of the metamorphic formations of the area in the past fifteen years, the lithostratigraphic units established by the Stratigraphic Commission of Hungary (SCH), FÜLÖP in his monograph and the MÁFI's mapping team show significant differences. This overview is based on the units established by the Metamorphic Subcommission of the SCH but several details are taken from FÜLÖP's volume (1990) as well.

In the Sopron Hills two basic units of the Central Alpine Crystalline Zone can be identified: the Grobgneiss and the Wechsel series. The former corresponds there to the Sopron Complex and the latter to the Fertõrákos Complex. The Sopron Complex (Sopron Crystalline Schist sequence — FÜLÖP 1990) consists mainly of micaschist of sedimentary and gneiss of intrusive origin. Its stratotype is the borehole Sopron S–8 which in addition to the "Sopronbánfalva Gneiss formation" encountered also the "Óbrennberg" and the "Vöröshíd Micaschist formations". A remarkably high biotite content is the main feature of the "Óbrennberg Micaschist" the maximal thickness of which is 250 metres. It is made up by the following rock types: andalusite-sillimanite-biotiteschist, disthene-chloritoide-muscovite schist and disthene-leuchtenbergite-muscovite-quartzite. The most common rock type of the "Vöröshíd Micaschist" with its minimum thickness of 250 metres is the chlorite-muscovite schist. In some cases paragonite, disthene-leuchtenbergite-quartzite and amphibolite can also be accumulated in the rock forming quantity. Its garnet-, graphite- or turmaline-bearing varieties are rare. According to FÜLÖP (1990) the original material of the micaschists might have been a sediment of Early Palaeozoic or perhaps Precambrian age. The sediment consisted of alternating clay and siltstone beds without carbonate or organic matter but with a few quartzose sandstone lenses.

The "Sopronbánfalva Gneiss formation" consists of medium grained muscovite–gneiss Is main minerals of which are quartz, feldspar, muscovite and occasionally biotite. Several of its altered forms are known, for instance the quartz-leuchtenbergite-muscoviteschist, the popular name of which is "leucophyllite". The complete thickness of the formation can be several hundreds of metres. According FÜLÖP (1990) the "Sopronbánfalva Gneiss" is a product of a granite intrusion of Variscan origin that is subsided down to the migmatite zone during orogeny and intruded in its middle phase into the sequence that underwent a high pressure regional metamorphism (amphibolite facies). During the Alpine orogeny the Sopron Complex underwent a retrograde metamorphism as a result of which diaphtoritic alterations extending up to the phyllonite can be recognised. Its further result is the transformation of granitic rocks into gneiss. The leucophyllite developed along thrust plains of the Alpine nappes. The motion surfaces of imbrication recognised in the area indicate a north-eastern vergency.

The surface occurrence of the **Fertõrákos Crystalline Schist Complex**, which is similar to the Wechsel series of the Lower East Alpine nappe system, is restricted to the Fertõrákos Schist Islet extended over the Austro/ Hungarian border. The formations of this complex are known in a south-eastern monoclinal setting with a 1500 metre thickness. This complex is divided into two interfingering "formations" and several "members" within them. The "Fertõrákos Micaschist formation" of an Early Palaeozoic or even Precambrian sedimentary origin consists of feldspathic, phyllonitic, occasionally of graphitic micaschists, crystalline limestone and dolomite and muscovite-microcline-albite gneiss. In connection with the gneiss distinguished as member rank by FÜLÖP (1990) the idea of magmatic origin has also been raised.

The formation of syngenetic basic magmas (mainly gabbro and basalt) has been referred to different names [FÜLÖP 1990: "Fertõrákos Amphiboleschist formation" IVÁNCSICS in GYALOG (ed.) 1996: "Gödölyebérc Amphibole-schist Formation"]. It contains the following rock types: diaphtoritic amphibolite schist, hornblende schist (sometimes with garnets), biotite schist, quartz-actinolite-albite schist, biotite-albite gneiss. Its mineral association comprises both progressive and retrometamorphic parageneses.

The Fertõrákos Complex, like the Sopron Complex, underwent a similar (Variscan) progressive metamorphism and then an Alpine retrograde one. It is the easternmost occurrence of the Wechsel series with north, north-eastern vergency caused by nappe formation. The tectonic elements are accompanied by smaller leucophyllite occurrences.

PERMIAN AND TRIASSIC

The remains of an originally much more extensive cover of the crystalline basement are now, due to pre-Neogene erosion, restricted to a few places and the content is reduced to Permian up to Middle Triassic sediments as a maximum. The series, with an (Alpidic) low-grade metamorphic overprint, starts with the so-called Alpine Verrucano. This is a breccia with components of the local underground (in the Leitha Hills called Scharfeneck-Arkose), finer grained, mostly phengitic schists and intercalations of acidic volcanics (porphyroids). Believed to be already Triassic, it is followed by the **Semmering Quartzite**, whose uppermost part shows a sericitic phyllite level, called Alpiner Röt. The Anisian consists of thin-bedded, dark grey dolomites, interfingering with sandy and schistose layers and cellular dolomites, upwards changing into well-bedded, partly dolomitic limestones. Although usually free of fossils, the Anisian age is proved by crinoids at two places (Wimpassing/Leitha, Deutsch Altenburg).

Late Palaeozoic formations of the Malé Karpaty Mts are sporadically represented by the **Devín Formation** composed of arcoses, arcosic sandstones and conglomerates. According to its superposition and correlation with occurrences in other mountain ranges in the Western Carpathians, the age of this formation is Permian. This has been deduced mainly from correlation with the considerably more widespread Permian formation in the neighbouring part of Austria (the Hundsheim Hills), where acidic volcanites were also described. The Devín Formation has been distinguished as a formal lithostratygraphic unit in profiles near Devín by VOZÁROVÁ & VOZÁR (1988).

The Lower Triassic is represented in the tectonic unit Tatricum in the Malé Karpaty Mts by the **LúΩna Formation**. The clastic succession is composed of quartz conglomerates, quartz sandstones and quartzites with well observable graded beddings in some beds. In the basal parts there also low-angle cross-stratification has been recognized. In the Devín area, these complexes occur in the hanging wall of the Devín Formation (Permian), but in other places they overlie directly the crystalline basement.

The Middle Triassic is represented by the **Gutenstein Limestone** and **Gutenstein Dolomite**. These are present in the form of smaller lenses mainly in the Devín area.

JURASSIC TO ?LOWER CRETACEOUS

The Jurassic and possibly Lower Cretaceous complexes of the Tatricum are represented by the Borinka sequence (MAHEfl *et al.* 1984). Four formations of the Borinka sequence are distinguished in the geological map. These are as follows: Prepadlé (Lower Jurassic), Marianka (Lower–Middle Jurassic), Slep˝ (Middle Jurassic), Somár (Upper Jurassic – ?Lower Cretaceous).

The **Prepadlé Formation** consists of Ballenstein (Borinka) limestones and carbonate breccia, designated also as extraclastic breccia. It may also contain quartzous sandstones alternating with biodetritic limestones. The separated part of the Prepadlé Fm is composed of polymictic breccia and brecciated limestones.

The **Marianka Formation** comprises mainly dark shales with manganolites and thin intercalations of calcarenites.

The **Slep˝ Formation** corresponds stratigraphically to the Middle Jurassic and contains prevailingly calcarenites with intercalations of marly slates .

The **Somár Formation** is the uppermost one. It is a polymictic breccia alternating with sandstones and extraclastic limestones.

Veporicum

The Veporicum is a higher tectonic unit of the Central Western Carpathians which is equivalent to the

Mittelostalpin in Austria. It is represented only by small exposures below the Tertiary and Quaternary complexes near the villages Plátovce, ≥eliezovce and Túrovce. These occurrences of the crystalline basement and terrigenous sediments of Permian–Lower Triassic age were correlated with the Veporicum by FUSÁN *et al.* (1987), and more precisely with the Southern Veporicum by VOZÁROVÁ & VOZÁR (1988). This unit is divided in the pre-Tertiary basement map into the Early Palaeozoic metamorphites and the cover sequences. The first one consists of phyllites, alternating with metaquartzites and intercalated metabasalt tuffs. Sporadically also metadiabases have been found. The cover sequence is represented by the Revúca Group (**Slatviná Formation** — **Stephanian, Rimava Fm** — Permian) and the Federáta Group (Mesozoic). The clastic succession of the Revúca Group is made up mainly by sandstone, conglomerate, locally with intercalations of schists and other metamorphic rocks (metasediments and metavolcanics). They were reported to occur the area between Levice and ˇahy by VOZÁROVÁ & VOZÁR (1988).

The Permian **Rimavica Formation** is represented in the majority of occurrences by arcoses, arcose sandstones, polymictic sandstones, variegated, prevailingly red shales, or fine-grained polymictic conglomerates. There are also certain areas with granitoids showing signs of contact metamorphism.

The Lower Triassic sequence is composed of quartzose sandstones, quartzites and quartzose conglomerates, that correspond to the LuΩná Fm (FEJDIOVÁ 1980).

The Northern Veporicum has not been distinguished in the geological map, but it is also supposed to be present in the pre-Tertiary basement.

KríΩna Nappe

This tectonic unit, derived from to the Northern Veporicum, is present in the areas of Tríbeè, PovaΩsk″ Inovec and Malé Karpaty Mts. It is designated as Vysoká Nappe (ANDRUSOV 1958) and on the territory of the present map is known only from the boreholes in the pre-Tertiary basement of the Vienna Basin.

Hronicum

This higher tectonic unit (ANDRUSOV *et al.* 1973) is present in the pre-Tertiary basement, mainly in the northern part of the Danube Basin, partly also in the Vienna Basin. This is the **MaluΩiná Formation** with Permian basalt bodies (VOZÁROVÁ & VOZÁR 1988).

Silicicum

This uppermost tectonic unit is represented by a Triassic sequence. Superficially we locate it, accordingly with the ideas by BIELY (1965, 1977) and FUSÁN *et al.* (1987) in the area of the so-called Levice Islands. It was supported also with older data by VOZÁR (1969, 1973) about the Lower–Middle Triassic sequences with the characteristic lithological profiles in correlation with the Drienka Unit and developments in the Muráò Mesozoic Unit (BYSTRICK″ 1964).

Vienna Basin

Tertiary

The formation of the Tertiary basins at the eastern margin of the Alpine mountain belt started with the termination of the alpine orogenic overthrusting and the uplift of the range. The Vienna Basin was formed as a pull-apart basin, due to an extensional tectonic regime, since the Early Miocene, while the main subsidence and basinal sedimentation in the Austrian part of the Pannonian Basin began in the Late Miocene. Older marginal deposits of the Middle Miocene age of little thickness are only locally preserved. Therefore there are some differences in details of sequences, especially concerning the former littoral zones.

The earliest sediments in the Vienna Basin are dated as Eggenburgian, the sedimentation continued up to the Late Pannonian, with gradually decreasing water salinity since the Sarmatian age. The DANREG area covers, besides the widespread Quaternary cover, only the marginal parts of the basin filling, including the quite similar sequence of the Eisenstadt Basin, with basal Badenian conglomerates in the surroundings of the Leitha Hills, followed by predominantly reefal and detritic Leithakalk or, only in a few places, partly marl. Various trans- and regressional phases in the Late Miocene produced more clastic sediments, mostly reworked older gravels or sands before the water finally retreated in Pannonian time. In the Sopron Hills and in their surroundings the Neogene sedimentary cycle with similar lithologic composition overlies directly the Palaeozoic formations. For details see the Kisalföld Basin.

In the Pannonian Basin the sedimentation started with coarse-grained clastic formations in the surroundings of the Sopron Hills, the Auwaldschotter, probably of Ottnangian age. Some authors correlate it with the Ruster Schotter, in the Rust Range, which is supposed to be Karpathian. The following sequence contains limestones, sands and clays of Badenian and Sarmatian and mostly finer-grained clastic sediments of Pannonian age.

The pull-apart type Vienna Basin has a two-storey setting. In the study area on the territory of Slovakia only the younger Vienna Basin is developed with the beginning of opening after the basin relief inversion between the Early and the Middle Miocene. Here the sedimentation started in the Early Badenian, but the oldest sediment outcrops in the eastern part of the Vienna Basin are Middle Badenian.

From the Middle Badenian **Jakubov Formation** only the Devínska Nová Ves Member crops out in the studied area. These sediments are represented thick granitoidic clastics, prevailingly breccia, deposited on the Lower Badenian **LanΩhot Fm** and are covered by the sediments of the Studienka Fm. The size of granodioritic blocks reaches 0.5 m, and/or even more. These sediments were deposited on subsided blocks of marginal faults. Their thickness exceeds 300 m. Laterally they pass westward into fossiliferous marine siltstones and claystones of basin facies.

The Upper Badenian **Studienka Formation** overlies Middle Badenian sediments or the pre-Tertiary basement (western and northwestern foot hills of the Malé Karpaty Mts). The formation consists prevailingly of marine sediments and its thickness is 400–600 m. The basin facies has dominant lithotypes: grey calcareous clay and silt with variable share of sandy layers. They contain marine fauna. In the upper, and/or marginal part of the basin there are also intercalations of lignite.

The marginal part of the Studienka Fm on the southwestern foothills of the Malé Karpaty Mts and in the area of Devínska Nová Ves and Borinka villages is made up by the Sandberg Mb with marine fossils. These are prevailingly sands with beds of conglomerates, breccia, calcareous clays, organogenic and organodetritic limestones (Litava limestone).

The Sarmatian **Holíè Formation** has been deposited either on the Studienka Fm or the pre-Tertiary basement. Its thickness ranges from several tens to several hundreds of metres (towards the basin). The basin facies represents a brackish-marine environment. Its dominant rock types are grey, greyish green, calcareous clays with sandy layers and locally with acidic tuffs. Near Dúbravka in the Malé Karpaty Mts marginal facies of the Holíè Formation is distinguished as Karlova Ves Member (NAGY *et al.* 1993). These are represented by sandstones with intercalations of fine-grained gravel, nubecularia oolite and serpulid-bryozoan limestones.

In the Lower Pannonian, without surface outcrops, there are thick intercalations of sands (*e.g.* the so-called main sand). The maximum thickness of Pannonian in the studied area reaches 300 m.

The Pannonian **Záhorie Formation** is the youngest Neogene sediment of the Vienna Basin in the studied area. This Upper Pannonian sediment contains caspi-brackish fauna. They are grey clays to claystones in the upper part with intercalation of sands. The sediments contain the abundant fauna of brackish to freshwater character.

Quaternary

The Quaternary in the Austrian part of the Vienna Basin is represented by various terrace levels. The highest, like the Mitterriegel-Schotter is almost on top of the Leitha Hills, are probably even still Tertiary in age. The main formations have been transported by the old Danube from north via the Marchfeld and the depression between Leitha Hills and Hainburger Mt, while in the later Pleistocene the terraces were produced by more local rivers and other directions. Owing to the tectonic interaction and a quite complex subsidence and uplift, the stratigraphy and correlation of the local formations are still unclear and interpreted in very different ways.

The fluvial sediments of the Zohor–Marchegg Depression of the Vienna Basin, forming a narrow graben limited with the Láb and Zohor–Marchegg faults, have varied and rather complicated settings. According to BAÒACK˝ & SABOL (1973) the superpositional filling is formed by the Middle Pleistocene (Riss) fluvial sediments of the Morava River (borehole K–8). The polycyclic development is characterized by alternating cycles of sandy gravels, eolian sands and flood loams and clays. The succession is thickening westward.

The upper middle alluvial fans are present between the localities Stupava and Záhorská Bystrica. Their age is early Middle Pleistocene. They consist of sandy gravels, of granitoids and quartz.

The oldest Middle Pleistocene terrace of the Morava Valley, called Devín-Nová-Ves terrace equivalent to the LuΩná-Bruty terrace along the River Hron.

In the surroundings of localities Záhorská Bystrica and Stupava sporadically preserved proluvial sediments are outcropping. These are sandy to loamy, more sorted gravels, filling the margin of the Lamaè–Stupava Depression. The rock fragments are semi-reworked blocks of granitoids, limestone and sandstone pebbles. The alluvial cones locally overlap with a thin cover of eolian sand.

The fluvial deposits of the Upper Pleistocene terrace are sandy, well-sorted gravel, sandy-gravel and sand, equivalent to the Práter terrace and spread along the state border with Austria from the village Kittsse up to the triple junction of the borders of Slovakia, Austria and Hungary. In the Zohor–Marchegg Depression the alluvial sediments overlap Middle Pleistocene terrace fluvial sandy gravels.

The thickest wind-blown sands occur in the Zohor–Marchegg Depression.

The Danube Basin

Neogene

Danube Basin is a thermal extension basin. The subsidence started at the end of the Early and the beginning of Middle Miocene. The main part of the syn-rift phase took place during the Middle Miocene and the post-rift, or thermal phase during the Late Miocene and the Pliocene. The sedimentation was accompanied by volcanism. The products of volcanism build up the eastern and north-eastern margin of the basin and are also buried by younger basin filling.

In the study area the oldest outcropping Miocene lithostratigraphic unit is the Lower Badenian **Bajtava Formation,** consisting of volcanoclastic sediments, calcareous claystones and siltstones with rich marine fauna. It is situated on the periphery of the volcanic complex of the Börzsöny Mts and the Burda Formation. The Bajtava Formation overlies transgressively and unconformably the ˇtúrovo Palaeogene (identical with the Palaeogene of the Dorog Basin), or on the pre-Tertiary basement. It has developed only in the partial ≥eliezovce Depression in the eastern part of the Danube Basin and its maximal thickness exceeds 1000 m.

At the base of the formation there are redeposited volcanoclastics, mostly tuffitic sandstones and calcareous claystones with marine fauna, intercalations of andesite conglomerates and epiclastic breccia. It is overlain by the volcanosedimentary Burda Formation, which laterally, (basin-wards) grades into the fine-grained tuffitic facies with intercalations of algal limestones and amphistegine sandstones. It is a transitional facies between the Burda and the Bajtava Formations.

The Middle Badenian in the studied area is not exposed. The ˇpaèince and Trakovice Formations have been described from boreholes.

The Upper Badenian **Pozba** and **Madunice Formations** overlie the Middle Badenian sediments, or unconformably the pre-Tertiary basement. The basal part of the formations is made up by conglomerates which are passing into sandstones. The main lithotypes are calcareous siltstones and claystones of grey colour with marine fauna and banks of sand and sandstone. They may also sporadically contain algal limestones.

The Sarmatian **Vráble Formation** rests trangressively and locally also unconformably on various Badenian formations, in the marginal part of the basin also on pre-Neogene rocks. Its greatest thickness is known in the Riπnovce Depression (1600 m; outside of the study area), while in the Blatné and Komjatice depressions it is 500 m and in the ≥eliezovce Depression only 300 m.

The lower part of the formation, especially in the ≥eliezovce Depression is composed of polymict conglomerates, oolitic limestones, sandstones with thin layers of biotitic acid tuffs and green and grey calcareous clays. The upper part of the formation is built up calcareous clays with thin layers of sandstones, and/or with coquinas of bivalves. There are also intercalations of gravel and small lignite seams. The formation contains brackish-water fauna.

The Pannonian **Ivanka Formation** is lying probably transgressively on the Vráble Formation and consists mainly of delta sediments. In the central part of the Gabèíkovo partial depression it is composed prevailingly by sandy sediments, while in the eastern part of the Danube Basin, (≥eliezovce Depression) by pelitic sediments. Northwards the formation is developed in transitional facies; sands are alternating with pelites. On the margins of the basin there are present conglomerates and in the upper part of the formation carbonaceous clays and lignite beds are also found. The fauna is of caspi-brackish character.

The Pannonian to Pontian **Beladice Formation** represents deltaic sediments conformably deposited on the Ivánka Fm. Its maximum thickness is several hundreds of metres. The prevailing lithotypes are greenish-grey calcareous clays with admixture of sand and clay and/or layers of sand, carbonaceous clays and lignite seams. The basal coarse-grained clastics are developed only on the margins of the basin. In the formation there are also carbonaceous clays and small lignite seams (near Báhoò and Beladice). The formation contains fauna of a brackish to strongly hyposaline lake.

The Dacian **Volkovce Formation** consists of lake-river sediments, deposited either on Pontian or on older rock complexes in the northern part of the Danube Basin. Its transgressive character is visible near ˇtúrovo (Gbelce locality) where it overlies the ˇtúrovo Palaeogene. The maximum thickness of the formation exceeds 1000 m. On the northern periphery of the basin the formation consists of gravels and sands — sediments of river deltas and alluvial fans. Southward, the variegated calcareous clays with layers of sand prevail in the basin facies. The latter contains lime, limonite and manganese nodules. The formation has a poor freshwater and terrestrial fauna.

Ipel' Basin

Tertiary

The Ipefl Basin (and the ˇtúrovo Palaeogene) in the southeastern part of the Danube Lowland have different sequences in comparison to those of the Danube Basin. As the ˇtúrovo Palaeogene consisting of Middle and Upper Eocene and Oligocene sediments (NAGYMAROSY 1990) is part of the Pelso Unit, therefore it will be discussed under the subheading Pelso Unit. The Ipefl Basin is built up of Oligocene and Egerian sediments. It is in connection with the more young Fiflakovo/Pétervására Basin located eastwards (outside of the map sheet). The youngest basin is the Novohrad/Nógrád Basin. The age of its sediments is Ottnangian to Karpathian. Between the sediments of two last named basins are located the continental sediments of the Bukovinka Fm.

The **Luèenec Formation** is made up by the oldest Tertiary (Egerian) sediments, outcropping in the Ipefl Basin. Its thickness in the western part of basin is ca 400 m. The main lithotype of formation is calcareous crumbling siltstone of grey colour with indications of slaty schlier. It contains a rich mollusc fauna. On the bedding planes muscovite flakes are concentrated. This lithotype is distinguished as a member-rank unit: Szécsény Schlier, while it is called **Széchény Schlier Formation** in Hungary. In the environs of Dolinka the Szécsény Schlier is overlain by deltaic sediments, in which, in addition to the calcareous siltstones, polimictic conglomerates (incl. carbonate rocks), sandstones, variegated calcareous clays and thin coal seams also occur. In the formation marine and brackish-water faunas are alternating (ˇÚTOVSKÁ-HOLCOVÁ *et al.* 1993). These deltaic sediments were defined as the Opatová Mb.

The equivalent of the Opatová Mb in the surrounding of ˇtúrovo is the **Kováèov Sandstone**, the thickness of which is some 180 m. It consists mainly of calcareous sandstones (incl. cross-bedded ones) and sands but siltstones, variegated (prevailingly green) clays, and conglomerates are also found. Faunas of marine, brackish-water and freshwater type are alternating (SENEπ 1958). This sequence is suggested to be of deltaic origin.

The Eggenburgian **Bukovinka Formation** is restricted to the eastern margin of the map sheet as denudation remnants and is lying unconformably on the Luèenec Formation. Its maximum thickness is only several tens of metres. It is composed of middle to coarse-grained polymict gravel, where, however, carbonate pebbles are missing. In the gravel there are intercalations of sand and variegated clay. Eastward in the Ipefl Basin rhyodacitic tuffs appear in the formation that may be equivalent to the **Gyulakeszi Rhyolite Tuff Formation** in Hungary. The formation does not contain marine fauna and according to the lithological composition and its variegated colour it is assumed to be fluvial.

The Ottnangian **Salgótarján Formation** is represented in the area by the Plachtince Member overlying the Bukovinka Fm. Its thickness can attain 50 metres as a maximum and is composed of grey crumbling claystones with slaty crumbling. The member does not contain marine fauna and is supposed to be lacustrine.

The Karpathian **Modr˝ Kameò Formation** develops gradually from the Plachtince Mb. Its overall thickness is about 50 metres in the area under study. The formation is divided into three members. The lower member is the Medok˝π Mb representing the beginning of a marine transgressive cycle. It consists of calcareous, fine-grained laminated sandstones and siltstones. The sediments contain mixed marine (mainly foraminifera) and brackish-water fossils (molluscs).

The middle member is called Krtíπ Sand. It develops gradually from the Medok˝π Mb. The sand is non-calcareous, medium-grained and contains marine fauna. It has intercalations of paraconglomerates and benches of quartzified sandstones, sporadically also with thin layers of clay.

The uppermost member of the formation is the Seèianky Member. It is greenish-grey, calcareous siltstone and claystone with irregular sandy lamination and slaty crumbling, thin intercalations of rhyodacite tuffs and tuffites accompanied by diatomitic clays. The member is rich in marine fauna and represents the culmination of transgression.

A time interval just after the Karpathian is characterized by regression and extensive erosion. At the beginning of Badenian the sea shortly encroached upon the Ipefl Basin and the Krupinská planina Plain. The sedimentation was strongly influenced by volcanic activity in the ˇahy–Lysec volcanotectonic zone.

The oldest sediments unconformably deposited on the Modr˝ Kameò Formation are those of the Príbelce Member, the basal part of the Vinica Formation (for details see at the Vinica Fm).

Volcano-sedimentary formations

Sarmatian and Badenian volcano-sedimentary formations outcrop in the bordering area of Podunajská paòva Basin and the ˇtiavnica, Börzsöny stratovolcano, forming the volcano-sedimentary structure of the Kováèovské kopce Hills (locality Burda) and the Belianské kopce Hills, the Krupinská planina Plain and the peripheral zone of the ˇtiavnica stratovolcano.

The products of the **Burda Formation** outcrop within the horst block in the Kováèovské kopce Hills (Burda), near the Slovak–Hungarian state border. The products of Early Badenian volcanism are overlain by volcano-sedimentary sediments of Early to Middle Sarmatian age.

The Burda Formation is the result of volcanic activity and processes of transportation of volcanoclastic material (amphibole–pyroxene andesites to pyroxene–amphibole andesites with biotite±garnet) into marine environment. The eruptive centres, in the form of submarine extrusive domes and extrusive breccia of amphibole–pyroxene andesite, are supposed to be the sources of majority of volcanoclastic material. Some products (pyroxene–amphibole andesite with biotite±garnet) were most probably transported from eruptive centres located in the area of the Visegrád Hills and the Börzsöny Mts in the Hungarian territory.

The eruptive centres are represented by submarine extrusive domes and extrusive breccia. The submarine extrusive domes are elliptical to roughly isometric bodies of 150ˇ200 m size. The lower parts are formed by massive andesite with blocky to irregular jointing. In the upper parts there is transition to vesicular and brecciated andesite, and even to chaotic breccia. On the edges of extrussive domes or in their upper parts the relics of original marine sediments can be found. The sediments have also been penetrated by extrusions.

Extrusive breccia represents the penetration of brecciated material through the former volcano-sedimentary facies near Chflaba village. The lava ascent along fractures was accompanied by intensive vesiculation followed by explosive disruption and creep of brecciated material on the sea bottom.

The bodies of submarine extrusive domes are closely associated with submarine breccia flows that are predominantly composed of juvenile material of coarse fragment to blocky character and with chaotic type of deposition. These brecccia flows were initiated in a tight relation with explosive disintegration of the extrusive domes, or in the relation with their collapse. Deposition in the form of debris flows with prevalence of fragmented material over the sandy matrix was identified in both the proximity of extrusive bodies and also in more distant areas. In contrast to submarine breccia flows the material of older volcanic structure has also been mobilized. The material is often polymictic with variable degree of reworking. The next chaotic breccia type differs in its polymictic character, higher proportion of reworked blocks and also higher proportion of fine-grained sandy to sandy-clayey matrix. Cavities after branches and trunks of trees are often present. These breccias, corresponding to lahars or a “mud flows”, are located in zones more distant from eruptive centers and in higher levels of the volcano-sedimentary complex.

The chaotic breccia bodies alternate with sorted, fine to coarse-grained breccia with grainy, sandy to sandy-clayey matrix. The described facies fall into the common category of epiclastic volcanic breccia.

The pyroclastic flows are spatially associated with bodies of extrusive breccia, near Chflaba village. Breccias consist prevailingly of coarse-clastic, strongly vesicular clastic material with variable pumice content. They are characterized by chaotic deposition, higher compaction degree and by the tuffitic matrix being "baked".

In the higher levels of the volcano-sedimentary complex occur pyroclastic flows of pyroxene–amphibole andesites with biotite.

The pumice tuffs and redeposited pyroclastic rocks are in the middle to upper levels of the volcano-sedimentary complex. On the southern slopes of the Kováèovské kopce Hills pumice tuffs are 5–15 m thick. Deposition of pumice tuffs took place by means of pumice flows, downfall from atmosphere and redeposition. The pumice tuffs represent the products of explosive volcanic activity of pyroxene-amphibole-biotite andesites.

The epiclastic volcanic conglomerate and breccia are present in both the lower and the upper levels of the volcano-sedimentary complex, representing products of the destruction of primary (former) accumulations. Epiclastic volcanic breccia — conglomerates of variable thickness in general separate the layers of chaotic breccia in the zones close to eruptive centres and the occur in greater thickness also in zones more distant from the eruptive centres.

The beds of epiclastic volcanic conglomerates are developed in similar position as the previous facies, characterized by high degree of reworking and distinct sorting and bedding. In the zone close to the eruptive centres predominate coarse to blocky epiclastic conglome-rates with the block dimensions above 25 cm, rarely up to 1–2 m, while in the more distant zone medium to fine-grained epiclastic volcanic conglomerates with pebbles of 5–15 cm prevail (mainly in the Belanské kopce Hills).

The Lower Badenian **Vinica Formation** comprises products of the Early Badenian andesite volcanism on the southern margin of the Krupinská planina Plain, extruded from numerous volcanic centers (mostly extrusive domes). Volcano-clastic material was transported and deposited in marine environment, in the littoral to sublittoral zone (KONEÈN˝ 1969, 1970). On the base of microfauna (KANTOROVÁ in ÈECHOVIÈ & VASS 1962) , with the indicators of nannoplankton zone NV–5 (LEHOTAYOVÁ 1964), the age of the formation corresponds to Early Badenian or Early Langhian (LEHOTAYOVÁ in VASS *et al.* 1979). The Vinica Formation is in equivalent position to the Burda Formation. Its thickness varies from several tens of metres (near to the eastern margin), up to 350 m in the internal parts of the Krupinská planina Plain (borehole CK–1).

Eruptive centers (submarine domes, extrusive breccia, dykes) outcrop in the volcano-sedimentary zone of NE–SW direction named as ˇahy-Lysec Zone (KONEÈN˝ 1977).

On the base of the Vinica Formation there are tuffitic sands with pebbles of non-volcanic rocks (now Príbefl Member, VASS 1977) in a thickness of 0–30 m. It overlies unconformably and transgressively the partly eroded Karpathian and Ottnangian sediments. The main rock type is tuffitic sand, often cross-bedded and with increased heavy mineral content of volcanic origin (amphibole, hypherstene, biotite, garnet). Interlayers of pumice-ash rhyodacite tuffs and small conglomerates with volcanic and non-volcanic material are also present. The Príbefl Member contains also isolated light, blue, sandy, layered algal tuffitic limestones (Kleòany, Vinica and Kosihovce). The texture and the lithology of the sediments indicate deposition in littoral, or deltaic environment (VASS 1977).

Eruptive centres are represented by:

a) submarine extrusive domes,
b) extrusive breccia,
c) dykes.

The extrusive domes consist of andesite bodies of elliptical to isometric shape from 80 to 120 m. The upper parts of the bodies are brecciated. The rock is amphibole-pyroxene andesite rarely with garnet.

The bodies of extrusive breccia piercing the Lower Badenian formations are of relatively smaller dimensions (50–80 m in diameter). After the subsurface brecciation the brecciated material was extruded on the sea bottom, and accumulated in the form of coarse debris, chaotic breccia, or was transported farther by means of submarine breccia flows. The grainy matrix is often oxidized (red-brown) showing higher degree of compaction.

The dykes represent prevailingly NW–SE striking bodies maximum 100–150 m long and up to 20 m wide. The margins of dykes are characterized by blocky jointing or narrow brecciation zones.

The coarse to blocky chaotic breccia are spatially associated with the bodies of submarine extrusive domes and extrusive breccias. The andesite fragments to blocks (up to 2 m in diameter) come from destructed extrusive domes. The matrix is coarse-grained, with fragments of vesicular andesites and pumices. In the zone around the eruptive centers there are bodies of chaotic breccia, separated by layers of epiclastic volcanic sandstones, breccias and conglomerates, corresponding to submarine breccia flows of monomictic character. They are characterized by chaotic deposition, high degree of compaction and consolidation of matrix. In the larger distances debris flows and subaqueus mudflows are common.

The poorly sorted epiclastic volcanic breccia contains facies of redeposited volcano-clastic material. For this unit low degree of sorting, polymictic character, higher degree of reworking of fragments and in general higher percentage of matrix are characteristic. This facies is wide-spread in the lower levels of the complex and in greater distances from eruptive centres.

Epiclastic volcanic conglomerates occur mainly in the western part of the formation. In the proximity of coarse-grained to blocky breccia coarse conglomerates (blocks above 25 cm) prevail. In the western part of the formation gradually become prevailing medium to fine-grained conglomerates, with pebbles 10–25 cm in size.

Fine-grained sediments occur in the lower to basal part of formation, and are represented mainly by tuffitic siltstones to claystones, often calcareous claystones, in the E, while in the SW, in the area of shallowing (Ipeflské Predmostie), there are tuffitic interalyers, layers of tuffitic sandstones and fine to medium-grained conglomerates.

The Middle Badenian **Èelovce Formation** is a product of explosive activity of pyroxene-andesite volcanism. It is overlying the Vinica Formation in the southern slopes of the Krupinská planina Plain. The formation is built up by epiclastic volcanic rocks (breccia, sandstones, conglomerates), pyroclastic breccia and explosion neck. The N and NE part of the Èelovce Formation consists dominantly of pyroclastic rocks, while the SW part was deposited in littoral zone of the Badenian Sea. The basal part (5–15 m) of the Èelovce Formation consists of tuffitic sands with pebbles of non-volcanic rocks unconformably deposited on the erosion surface of the Vinica Formation. The pebbles of non-volcanic rocks represent crystalline rocks (granitoids, crystalline schists) and Mesozoic rocks (quartzites, limestones).

The eruptive centre is represented by an explosion neck of roughly isometric cross-section, formed by neck breccia cut by andesitic dykes. Pyroclastics are represented by chaotic pyroclastic breccia, with volcanic bombs, blocks and cinder-lapilli matrix. The rare outcrops of chaotic breccia SW of the neck are pyroclastic flow deposits. The pyroclastics (blocks and tuff matrix) are partly welded.

The coarse-grained epiclastics are represented by epiclastic volcanic breccia and lahar breccia (type of cold lahar). The coarse to blocky lahar breccia of 5–15 m in thickness is characterized by non sorted polymictic volcanoclastic material with sandy matrix and chaotic deposition. There are also sorted and stratified epiclastic volcanic breccia with fragments of 10–15 cm in diameter, representing sediments of hyper-concentrated flows and debris flows.

According to granulometry, within the wide-spread epiclastic volcanic conglomerates: a) coarse epiclastic conglomerates (with blocks above 25 cm), b) medium to fine epiclastic conglomerates (below 25 cm) are distinguished. The coarse conglomerates form thicker bodies (5–15 cm). Their matrix consists of coarse-grained sandy material, with distinct sorting and stratification.

The epiclastic volcanic sandstone is the next wide-spread facies in the SW part of the formation. Medium-grained epiclastic volcanic sandstones of sorted to well sorted character (type of playa sands) predominate. Subordinately, interlayers of fine conglomerates and siltstones also occur. Locally non-stratified sandstones with fragments to blocks of siltstones and scattered andesite boulders of conglomerate type occur near the Hruπov village, suggesting transportation of material by mass flows. Some textures point to transport by means of grain flows and hyperconcentrated flows.

ˇTIAVNICA STRATOVOLCANO — PERIPHERY ZONE (BADENIAN)

The periphery zone of the ˇtiavnica stratovolcano is located in the N part of the map sheet. It is represented by epiclastic volcanic rocks, which are in lateral contact with facies of the Èelovce Formation. The deposition of the volcano-sedimentary layers took place in the littoral to sublittoral zone of the Badenian Sea. The facial unit in the wider area of the Pláπ∫ovce village is named the Pláπ∫ovce Member (VASS 1971).

The wide-spread epiclastic volcanic sandstones are medium to coarse-grained, often with interlayers of fine conglomerates. The sandstones are sorted, stratified, cross-bedded, gradationaly bedded, often with textures of mass transport. They often contain fragments of fine-grained sediments and andesite pebbles. Petrographically these are fragments of pyroxene and amphibole–pyroxene andesites. The matrix contains fragments of phenocrysts, glass and pumice. Epiclastic volcanic sandstones alternating with siltstone outcrop southward of the Pláπ∫ovce village. The siltstones of considerable volume originated from volcanic ash. The stages of quiet sedimentation were interrupted by abrupt influx of more coarse material in the form of epiclastic volcanic sandstones. The presence of fragments to blocky siltstones and andesite boulders in silty material documents mass movement due to gravitational slides (near Pláπ∫ovce village). On the prevolcanic basement outcropping at the Túrová village lies the Túrovce Member. It is a freshwater sediment consisting of quartz gravels and sands. The Túrovce Member developed during the Early Badenian before the transgression. It is overlain by a volcano-sedimentary sequence of Middle Badenian age — the Pláπ∫ovce Member.

More to the south in the peripheral volcanic zone there are sandy tuffites. The prevailing types are medium to fine-grained with numerous interlayers of siltstones and fine grained conglomerates.

Tuffitic siltstones and claystones and fine-grained sandstones are present in the more continuous profile exposed west of Pláπ∫ovce village. Subordinately they contain layers of fine-grained epiclastic volcanic sandstones, which thickness decreasing towards the S while clays with siltstones gradually form thicker layers. Tufftic limestones and calcareous nodules are to be found near the Horn˝ Túrovec village.

The volcano-sedimentary complex of the peripheral zone of the ˇtiavnica stratovolcano is dated by means of the microfauna found in the borehole GK–3 (0–230 m) as Middle Badenian (LEHOTAYOVÁ in KONEÈN˝ *et al.* 1966).

Epiclastic volcanic conglomerates are present either as individual horizons of varying thickness, or form interlayers and lenses within layers of epiclastic volcanic sandstones. Coarse epiclastic volcanic conglomerates with prevailing boulders above 25 cm, rarely even to 1 m, are wide-spread over the northern margin of the territory. Towards the south there is a gradual transition to the medium to fine conglomerates. The conglomerates are dominantly sorted and stratified. They often contain interlayers of epiclastic volcanic sandstones. The conglomerates of slided bodies differ by a low sorting degree and the higher proportion of sandy matrix (40–70%). In the conglomerates the following rock types are present: pyroxene andesites (augite-hyperstene, hyperstene-augite) and pyroxene andesites with amphibole, and occasionally andesite porphyries and hyperstene-amphibole andesites with accessory biotite and garnet.

Polymictic conglomerates with volcanic and non-volcanic material are rarely found in the vicinity of the outcrops of basement rocks, near Horné Túrovce village. The substantial volume consists of metamorphites and Mesozoic rocks (limestones, quartzites). The matrix is coarse-grained, sandy, of polymictic composition.

ˇtiavnica stratovolcano — peripherial volcanic zone (Sarmatian)

Above the Badenian volcanosedimentary complex in the western part of area there is a volcanosedimentary complex of Early Sarmatian age. Its texture and lithology indicate deposition in shallow-water environment in the littoral to sublittoral zone.

Medium to fine-grained epiclastic volcanic sandstones with interlayers of conglomerates compose the bulk of the volcano-sedimentary formation. They are characterized by distinct sorting and stratification (gradational, oblique and cros-bedding). There are also numerous interlayers and lenses of fine conglomerates 2–5 cm in diameter, siltstones and claystones, (often with plant remnants), coarse-grained sandstones and pumice tuffs.

The epiclastic volcanic siltstones and claystones form discontinuous layers, alternating with epiclastic volcanic sandstones. The sediments are ochre to light-grey in colour and display irregular-conchoidal fracture. Plant remnants and scarcely distinguishable, weak imprints of marine fauna are common. Rounded fragments of andesite pumice are also present.

Pumice tuffs in the form of thicker layers (1–5 m) outcrop in the western part of the volcanic area (Demandice village), within the layers of epiclastic volcanic sandstones. The pumice tuffs are light-grey in colour with higher content of pumice (30% and more). They are 1-2 cm in average and are dispersed in darker grey tuffitic matrix. There are also present fragments of black vitreous, or strongly vesicular pyroxene andesite. The material of pyroxene andesite is proved by petrography. The Early Sarmatian age — Volhynian of is documented by macrofauna (Ondrejièková 1980).

Quaternary of the Danube Lowland

The sediments in the Lamaè gate at the contact of the Malé Karpaty Mts and the Záhorie Lowland are stratigraphically problematic. The residue of gravels and conglomerates is ranged by Baòack˝ & Sabol (1973) into the older Middle Pleistocene (Mindel and pre-Mindel).

In any case, these are the residue of a reworked coarse gravel consisting prevailingly of pebbles of quartzite and quartz, forming alluvial sediments, locally tightly related with the underlying conglomerates. The morphological position of the sediments of the Devín-Nová-Ves terrace does not exclude the possibility that these are the basal beds of the Early Pleistocene, locally cemented with calcite and limonite. It is supposed to be a deposit of a palaeoriver that flowed through the Karlova Ves water gap cut in the Early Pleistocene. It is not excluded that through the Lamaè gate it flowed also in the lower part of the recent Mlynská dolina Valley.

The Quaternary history of the DANREG region is closely related with the development of the Danube and its tributaries, the Morava, Váh, Nitra, ≥itava, Hron and Ipefl/Ipoly rivers, as well with complicated neo-tectonic movements and climatic changes. The Quaternary deposits are fluvial, transitional fluvio-limnic, proluvial and deluvial sediments of the foot hills of the Malé Karpaty Mts, the Krupinská planina, Kováèová kopce Hills (Burda), covers of loesses, loess loams, plateau, wind-blown sand, slope sediments and travertines. They are divided into Lower, Middle and Upper Pleistocene and Holocene.

Pleistocene

Lower Pleistocene

The fluvial-lacustrine sediments are the oldest Pleistocene formations of the region that are filling the deepest central (Gabèíkovo) depression of the Danube Basin. They are overlying the Neogene and ranged to the Kolárovo (Gabèíkovo) Member (sands, silts). In the marginal parts of depression they are lying on the calcareous gravel of the Palárikovo Member.

The Kolárovo Member is distinguished from the middle fluvial formation of the Early Pleistocene (Janáèek 1967). It is called Palkovièovo Member by Halouzka & Minaøíková (1977). In the centre of the Gabèíkovo Depression the described sediments were found in the maximal depth of 380 m (borehole PA–1), and 450–500 m (geophysical measurements). This varigated sandy-gravel is often clayey and loamy.

Quartzite, quartz, silicite/limestone and dolomite are the dominant rock types of the sandy gravel of the formation. In the association of minerals is very conspicuous the high number of carbonates (Hornіπ & Priechodská 1979).

The fluvio-limnic gravels and sands are prevailing in the formation. These are fine, mostly medium-grained to coarse grained, polymictic, locally mica-bearing. Of stratigraphic importance are clay-loam layers, with a maximum thickness of 30 m.

The important palaeontological remnants are the ostracodes (Brestenská 1977), and the spores (Planderová 1977).

In the river valleys of the Trnava, Nitra, ≥itava, Pohronie and Ipefl Upland, the Ipefl Basin and partly the Záhorie Lowland, Lower Pleistocene terraces occur. In the ≥itava and Hron valleys there are three of them.

The oldest (Biberian) sediments are represented by the Strekov Member of the Strekov-Svodin terrace (Harèár 1967). It consists of gravel that is considerably weathered and periglacially deformed. It contains limonite nodules and remnants of vertebrate fauna.

The middle **Svodín Member** (Baòack˝ *et al.* 1993) is made up by the Svodín level of residual gravel (Harèár 1967) outcropping sporadically in the Kováèová kopce Hills.

The lower (?)fluvial sediments of terraces and proluvial sediments of alluvial cones are called Ludin-Bruty terrace. The terrace gravel has a maximum thickness of 7 m (HALOUZKA in VAπKOVSK˝ *et al.* 1982). It consists of quartzites, quartz, andesites, rarely also granitoids.

Occurrences of proluvial gravel are found on the Trnava Upland and the western foothils of the Malé Karpaty Mts. These are residue of gravel and blocks of alluvial fans, consisting of the coarse semireworked pebbles of the Malé Karpaty quartzites and granitoids.

Interglacial soils of the Lower Pleistocene are known under loess cover in the Pohronie, Nitra, ≥itava and Trnava Upland.

MIDDLE PLEISTOCENE

The extensive, mainly fluvial sedimentation of the Danube River and its tributaries (Morava, Váh, Nitra, ≥itava, Hron and Ipefl/Ipoly) is characteristic for the period of the Middle Pleistocene with subsidence in the Danube Basin.

The slightly uplifted parts of the uplands are characterized by the most distinctive terrace formation of the Morava, Váh, Nitra, ≥itava, Hron, Ipefl/Ipoly rivers and their tributaries and with starting loess sedimentation. In its central part and along the River Váh chiefly middle fluvial sandy-gravel formations of huge (deltaic) flat alluvial fans have developed. They are designated as the "Danube River gravel formation".

The magnetic inversion corresponding to the boundary Brunhes-Matuyama, *i.e.* to the Cromer interglacial (VAπKOVSK˝ & VAπKOVSKÁ 1977) was determined from loamy-clayey intercalations.

The Blatná and Galanta downwarps of the marginal parts of the Danube Basin are filled by fluvial sandy gravel. They crop out only in the central part of the core of the ≥itn˝ ostrov. The middle formation of cyclic character is made up prevailingly by gravel, sandy gravel and sands with rare intercalations of clayey, or loamy sediments. The predominant rock types of the pebbles are quartz and quartzites (MINAØÍKOVÁ 1968), but less often silicites, sandstones, limestones, dolomites, gneisses and granitoids are also found.

The fine-grained (loamy-clayey) fraction of the upper formation often forms lenses that have been dated Riss–Würm and Mindel–Riss interglacial on the basis of their interglacial fauna (SCHMIDT1977).

From the Early Pleistocene travertines are present in the Danube area outcropping in the surroundings of Dudince village. They consist of compact, slightly cavernous travertines, in which an incomplete proboscidean *Archidiskodon meridionalis* (NESTI) SCHMIDT (1977) was found. This allowed to range the travertine into the Lower Pleistocene. This sedimentation continued there with compact travertine in the Middle Pleistocene and also in the Holocene.

The oldest Middle Pleistocene (Mindel) is represented by the LuΩná-Bruty terrace along the Hron River (HALOUZKA in VAπKOVSK˝ *et al.* 1982). Equivalents to this terrace are present above loess cover on the Zalaba bar, in the old ≥itava and Ipefl/Ipoly valleys. This terrace accumulation consists of sandy gravels, which are locally strongly weathered, loamed. Their markedly rounded pebbles are quartzite, quartz, crystalline schists, limestones and andesites.

The Middle Pleistocene terraces morphologically either form individual benches, or are twinned. The higher terrace (Early Riss) has been preserved here and there on both sides of the Hron Valley, sporadically also in the lower flow of the Ipefl/Ipoly River and at the confluence of Váh and Danube rivers. The middle terrace in the Danube Valley is designated as the Buè-MuΩfla, Lafrankony, Bratislava terraces. As a result of unequal neotectonic movements the base of terrace bench is present in various heights.

The coarsest reworked and sorted sandy gravel is found at the base of fluvial accumulation, which is locally bound by limonite, or more weakly with calcareous cement. Upwards it becomes finer, cross-stratified, and regularly passes into middle to fine-grained muscovitic sands and flood loams, which are locally washed-out or disturbed with cryo-turbation and overlapped with fluvial gravel of the next accumulation (twinning of sedimentation — VAπKOVSK˝ *et al.* 1982). In the petrographic composition of the terrace resistent pebbles of quartz and quartzite predominate. This fluvial sequence is covered by loess. In the southwestern part of the Pohronská pahorkatina Hilly Land fluvial sand and flood loams crop out.

The alluvial cones are well preserved at the eastern foot of the Malé Karpaty Mts, filling up the Pleistocene Pezinok–Modra Depression, and also on the Trnava Upland. The cone accretions consist of coarse-grained semi-reworked to reworked pebbles and sands of quartzites, less often granites, quartz schists and limestones.

UPPER PLEISTOCENE

The Upper Pleistocene is present in the larger part of the Danube territory and is represented by freshwater limestones–travertines, fluvial sediments, fluvial-eolian, but mainly eolian sediments.

A considerable part of the area is formed by travertines developed at the boundary zone of the Upper and Middle Pleistocene. The travertines on the southern slope of the ˇtepnica Hill overlie fluvial gravels, but mainly the clays of the middle terrace. They are grey to brownish-grey, compact and very distinct products of the Riss–Würm interglacial.

The proluvial sediments of the Upper Pleistocene (Würm) form a narrow rim in the lower part of the western and eastern foot of the Malé Karpaty Mts. They are flat-lying alluvial cones of water flows from the Malé Karpaty Mts formed by non-sorted, non-rounded gravel and sand with the predominance of pebbles, blocks, fragments of granitoids, sandstones and quartzstones.

The fluvial sediments of the low terraces are sporadically preserved in the Danube, Morava, Váh, ≥itava, Hron and Ipefl/Ipoly valleys and their tributaries where they crop out in form of terrace bench.

The river floor sediments cover large areas of the river plains of the Danube and its bigger tributaries (Váh, Nitra, ≥itava, Hron and Ipefl/Ipoly) but they crop out only on the terraces as the youngest glacial (or stadial) cycle of saturated, well-sorted are sandy gravel and sand. The cover of the low terraces of the Upper Pleistocene (Würm) are sands at the mouth of Hron and ≥itava rivers, fine-grained, with clay intercalations. The elevations of the low terraces and floor accumulation are occasionally built up of clay loams and fine-sandy loams of Late Pleistocene age.

The fluvial-eolian calcareous sand is an individual category of sediments in the Danube Valley deposited on the lowermost bed of the Danube (Èenkovsk˝ les forest). This is fine-grained sand but it eventually contains coerser intercalations (coarse-grained sand to fine-grained gravel).

Eolian sediments —loesses are wide-spread in the Danube region. They almost continually cover the territory of the Trnava, Nitra, ≥itava, Pohronie and lpefl/Ipoly part of hilly land and the terrace beds of the Danube and its tributaries. They markedly obscure the primary relief. Loesses can alternate or interfinger with slope sediments and fossil soils. Their most important outcrops in the region of study are as follows: Senec, Vlèkovce, Komjatice, Tvrdoπovce, ˇurany, Jursk˝ Chlm, ˇtúrovo, Kamenica nad Hronom, Pastovce, lpeflsky Sokolec, V˝πkovce, Balog nad Ipflom.

Coarse silt is the prevailing fraction of the loess. Its carbonate content ranges between 6–30%, which can be dispersed or concentrated in concretions and in the lower part of fossil soil horizons. Loess can contain characteristic malacofauna, occasionally vertebrate fauna, volcanic ash (Senec, Komjatice) and archeological findings.

The bulk of loess was formed in the Middle and Late Pleistocene. In the interbeds of Váh, Nitra and ≥itava rivers Holocene swampy loesses are also known.

Wind-blown sand is a characteristic Quaternary sediment of the Danube Basin. Its occurrences are connected with the lower parts of lowlands, along larger water flows (Podunajská níΩina/Danube Lowland). The morphology of wind-blown sands is prevailingly longitudinal, parabolic, but arc dunes, locally dunes also occur. The stratification of the wind-blown sand is often highlighted by the the grain-size composition and limonite admixture. It is mainly porous and fluffy.

The majority of the wind-blown dunes developed in the Middle and Late Pleistocene, however, they are also known from the Late Glacial, Würm and Holocene.

Pleistocene–Holocene

Deluvial sediments form a discontinuous and very irregularly thick cover and differ by their material. Deluvial (slope) loamy-rocky sediments mainly flank the lower parts of the eastern slopes of the Malé Karpaty Mts, the Krupina planina Plain and the Kováèová kopce Hills. These are the weathering products of volcanoclastics, crystalline and Mesozoic complexes, transported by solifluction and gravitational movements. The bulk of the coarse-detritus was formed in periglacial time (Würm) by intensive mechanical weathering.

Deluvial loamy sand occurs on slopes in the area of Neogene sands (Pohronská pahorkatina), loess fields owing to short resedimentation. Deluvial loess loams are also found on slopes and foot of the hills forming decalcified loams with transported pre-Quaternary sediments.

The Danube Plain was made up by fluvial layers of sandy gravel during the intermediate time from the Pleistocene to Holocene (uphill core of the ≥itn˝ ostrov).

Along the low terrace of the Danube and the core of the ≥itn˝ ostrov older Danube aggradational levee sediments, called "PetrΩalka terrace", are developed. The levees are composed of fine to medium-grained sands with sandy gravel in spaces between levees.

Holocene

The Holocene sediments are composed of the lithofacially varied upper formation (flood plain) of the Danube and its tributaries.

Deluvial-fluvial sediments form filling of the dry bottom and the spasmodic water flows on the bottoms of water-cut valleys of hilly-lands. Their lithology is extremely varied.

Holocene travertines are developed as distinctive, small, layered travertine mounds on the same area as the Pleistocene, with sinter intercalations and Holocene malacofauna.

Transitional type moss bogs (Vaπkovsk˝ & Vaπkovská 1977) developed in the Danube Lowland, mainly in the abandoned dead arms of the Mal˝ Dunaj River (Little Danube) and in the small foothill depressions of the Malé Karpaty Mts. According to Krippel (1965), the alder, beech, abies and oak-tree pollens prevail in the pollen spectra of bogs.

Lithofacially the Holocene proluvial sediments are divided into gravel and loamy types. The loam gravels occur on the footwall of the Malé Karpaty Mts, the Krupina planina Plain and the Kováèová kopce Hills. The material consists of fragments of andesite, quartzite, quartz, granitoids and limestones. Sandy loams are present at the contact of alluvial plains and lowland hills.

Out of the fluvial plain facies of broader sense sandy gravel is prevailing. It is found among natural levees and near-levee space along the Danube and the Little Danube. The sands of near-river-bed flats and aggradational levees form morphologically elevated plains in connection with larger rivers.

The loamy, sandy-loamy flood sediments are important constituents of the river plains of the Danube and its tributaries. Strongly humusoid loams of rot-muds and weakly humusoid alluvial loams of silty to sandy-clayey content fill the older dead river arms.

The anthropogenic sediments include a great variety of products, mainly in connection with the construction of embankments.

Pelso Unit — Transdanubian Range

Palaeozoic

On the surface of the relevant part of the Transdanubian Range there are no Lower Palaeozoic to Lower Triassic formations. The Palaeozoic formations of unknown age deriving from the basement are known to occur only as xenolites in the andesitic rocks of the Dunazug/Visegrád Mountains brought to the surface by volcanic activity. LENGYEL (1951) reported the following rock types: granite, diorite, peridotite, cordierite hornfels, cordierite-andalusite-hornfels, crystalline limestone and dolomite, gneiss, amphibolite, micaschist and hornfels.

Mesozoic

Triassic

On the surface, the oldest Mesozoic formations are found in the Buda Hills. Our knowledge on the Buda Hills Triassic is unreliable and insufficient, in spite of the comparatively good outcrops and their nearness to the research institutions. Although quite a number of experts spent time studying the Buda Hills, but never within the scope of a programme aiming at an overall assessement of the region. By now it has become obvious that the area has a much more complicated geological setting than a reliable geological model could be set up without being supported by appropriate palaeontological and sedimentological research. Several ideas have been drawn up on the Mesozoic geological structure of the region as far as the age of formations, conditions of sedimentation and its structural system are concerned, but since they were based on incomplete data it was always easy to come up with effective arguments against them. In addition to the unsystematic research the reason of the above mentioned situation can be sought in the significant differences within this comparatively small area occurring not only in the particular structural build-up but also in the sedimentary environment. These differences were made almost unrecognisable by the subsequent changes.

Different structural elements can be found in the Buda Hills and in its surroundings. The recognition of the horizontal movements is due to SZENTES (1934), who proved a Pyrenean phase (post-Eocene) movement on the Péter Hill. The imbricate structure was first recognized by PÁVAI-VAJNA (1934) in the Raibl beds of the Gellért Hill. According to HORUSITZKY (1943, 1958–59) the "cherty Triassic facies unit" crops out as a half window from under the dolomites and limestones of the "Pilis–Nagykovácsi facies unit". The origin of the Triassic facies zones, recently oriented NW–SE was dated by WEIN (1977) for the Middle and Late Triassic but perpendicularly to their recent orientation. According to him the development of the parallel arrangement of these facies zones —with two basins (cherty limestones, cherty dolomites and marls)— to the axis of the syncline of the Transdanubian Range can be traced back to the changes in the conditions of sedimentation. He connected the change of strike to the Austrian-Mediterranean structural movements. He named it the "Buda strike-fault Zone". It is also considered to be the age of the SE-oriented overthrust of the "Buda Nappe" that is expressed in the overthrust of the Buda Hills on the eastward continuation of the Balaton Line.

The relatively detailed summary given above seems necessary since there is no clear, generally accepted model explaining the contradictory phenomena in the Buda Hills. In addition to the presentation of the geological formations a preliminary model will also be outlined in connection with the basement map.

Its oldest formation found on the surface too, is the **Budaörs Dolomite Formation** that is classed to the Ladinian stage of the Triassic. According to HAAS's latest definition (1993) it is a grey and off-white, generally well-bedded and cyclic dolomite with Dasycladacean algae. Its most common fossil is the *Diplopora annulata* that in some banks can be found in rock-forming quantity while in others it is untraceable. In addition to this, a few gastropods and also foraminifers in thin-sections can rarely be found (ORAVECZ-SCHEFFER 1987). The texture of the formation of shallow carbonate platform is a completely recrystallized, inequigranular dolosparite.

The Budaörs Dolomite has two areas of occurrence in the Buda Hills. The Csiki Hills, the type locality of the formation, are outside the DANREG map sheet. It can also be found in typical development in several points of Nagyszénás Mount north of the Nagykovácsi Basin. Along a short section the northwards dipping formation is in tectonic contact with the Dachstein Limestone Formation. In the north it grades into the Main Dolomite Formation (Hauptdolomite) from which is difficult to distinguish it if no Diploporas are present. Therefore the above-mentioned arrangement of the formations in the north-western part of the hill can not be considered reliable without further thorough research. Although the contact of the Budaörs Dolomite and the Dachstein Limestone shows a horizontal movement, it is evident that the original contact can be explained with an imbrication.

The specific formation of the Buda Hills is the **Mátyáshegy Formation**, the composition of which has not been cleared up yet. According to HAAS's definition (1993) it is a limestone in the lower and dolomite in the upper parts with marl intercalations in both rock types. In accordance with this, the Mátyáshegy Limestone and the Sashegy Dolomite Members are distinguished. Chert modules and lenses are characteristic for both rock types, but there are some parts without chert. The formation is a typical basin facies sediment. The colour of the well bedded Mátyáshegy Limestone varies from light-grey to yellow-brown and is featured by undulating bedding planes. Its texture in thin-section is bioclastic micrite or biopelmicrite. Its characteristic fossils are as follows: sponge spicules, ostracods, and planktonic shell filaments, with some conodonts and radiolarians (KOZUR & MOCK 1991).

The **Sashegy Dolomite** is made up of well bedded grey dolomites and clayey dolomites with dolomicrosparitic or fine-grained dolosparitic textures. It was deposited in a semi-restricted basin under the wave base. Its age can be only roughly estimated as Carnian, probably Norian, but Rhaetian can not be precluded either. Therefore the formation is a heteropic facies of the Veszprém Marl, probably of the Main Dolomite, and perhaps even of the Dachstein Limestone as well.

However rather uncertainly, a dolomite body without cherts has been distinguished under the preliminary name **Hármashatárhegy dolomite**. This dolomite has a transitional feature between the dolomite of the upper member of the Mátyáshegy Formation and the typical Main Dolomite. According to Pelikán's observation (oral communication) the rock often contains synsedimentary breccia grains but sometimes crinoidal fragments even brachiopod and shell valves can also be found. The limestone intercalations within the sequence dominated by dolomite are also common. According to Pelikán the original sediment is a typical slope facies that was consolidated in the form of limestone, and its present lithological composition is a result of irregular postdiagenetic dolomitization.

The **Csõvár Limestone Formation** resembles the Mátyáshegy Formation. It occurs on the surface in the Danube East Side Block out of the DANREG map sheet. According to Kozur (1993) within this formation comparatively numerous conodonts and radiolarians are present not only in the Rhaetian but also in the Hettangian (*sic!*) stages. Recently some ammonites have also been found that also prove the presence of the Hettangian and perhaps Sinemurian stages in similar facies (Haas *et al.* 1997).

The **Main Dolomite** (Hauptdolomite), as its name suggests, is a well known and wide-spread formation in the Alpine facies belt. In fact, it is the most wide-spread Mesozoic formation also in the Transdanubian Range. The dolomite occurrences are numerous not only in the Buda Hills but also in the Pilis and in the South Gerecse Mountains. According to Haas (1993) the one and a half or two thousand metres thick light-grey, grey, mainly well-bedded lofer cyclic dolomite underneath the Dachstein Limestone is considered as the Main Dolomite Formation. The two most important elements of the lofer cycle are the thick-bedded member C and the algal mat member B. The green or red rather clayey member A representing the paleosol horizon, rarely joins the previous members. In the Buda Hills its ammonite- and brachiopod-bearing variety with a few lofer cycles is distinguished as the Vadaskert Dolomite Member. The peritidal sediment was transformed into dolomite during the early diagenesis. In spite of the fact that most of these occurrences are free from fauna in some cases it is relatively rich in fossils: megalodus, other bivalves, gastropods, foraminifers, ostracods and Dasycladacean algae).

The **Feketehegy Formation** (Haas 1993) consists of grey or brownish-grey, platy or well-bedded limestone and dolomite varieties, sometimes with thick fossiliferous limestone beds. Its member-rank lower part is dominated by dolomite and the upper part mainly consists of limestone. The former is laminated and highly bituminous, while the latter can be characterised by coquinass of oblique stratification and by graded calcarenite beds. A part of the bioclasts and the few ooids and oncoids are of allodapic origin. The coquinas are prominent with their rich and varied fossil content: bivalves (Avicula, Halobia, *etc.*) gastropods, ammonites, algae, ostracods, foraminifers, conodonts and sponge spicules. The sedimentary environment supposed to be a shallow, shelf basin restricted to varying extent. The age of the formation is Middle and Late Norian. The formation is confined to the northern part of the Pilis Mountains where it is approximately 300 metres in thickness.

The **Dachstein Limestone** is also a wide-spread formation in the Transdanubian Range, including. the Buda Hills, the Pilis, and the Gerecse Mountains. According to the formal definition given by Haas (1993) this formation has light-grey or white colour and lofer cycles, the elements of which vary extremely. It was formed in the different levels of the peritidal zone of the carbonate platform. Its common components are the members B and C. Although different types of development are known (rich in Megalodus, Triasina and Oberhauserella or coral, oncoidal) only the transitional interval between the Main Dolomite and the Dachstein Limestone (Fenyõfõ Member) has been distinguished so far as a member-rank unit. Its original thickness exceeds one thousand metres.

The age of the formation at Nézsa close to the eastern border of the map sheet ranges from the end of the Carnian to the Rhaetian, while the oldest beds westwards get younger (Late Norian–Rhaetian).

Jurassic

In the Transdanubian Range between the Dachstein Limestone and the Pisznice Limestone Formation at least a half a stage hiatus is proved. The red sediments of ammonitico rosso facies characteristic for the Tethys appear only in a few km-wide belt along the Danube between Tata and the Pilis Mountains. The most important outcrops of the Jurassic are in the Gerecse Mountains where two types are distinguished. The sequences of continuous sedimentation were developed in the basins whereas the discontinuous ones on the one-time highs. The former is characteristic for the East Gerecse and the latter for the West Gerecse. The magnitude of the hiatus in the discontinuous sequences varies. Usually there are no sediments from the Toarcian (possibly Pliensbachian) to the Oxfordian, but this interval evetually can be broader or narrower. Each ammonite zone can not be proved in the sequences of continuous sedimentation either but only a few zones are missing altogether, thus the sedimentation was only quasi-continuous. The extent (border) of the two sequences can be drawn with certainty in spite of the restricted extent of the formations and the relatively small number of outcrops. Along the highs bordered by steep fault plains the altitude difference increases step by step. Going upwards, on each step the lack of sediments usually increases. Along the slopes *i.e.* at the margins of the basins, the number of allodapic limestone varieties increases. The most important extraclasts are the crinoid fragments but the slope-breccias transported gravitationally (slumps or turbidity currents) are not rare either, especially in the Upper Jurassic. Away from the highs, the gravitationally transported clastics disappear gradually while the proportion of sediments transported in suspension and of the pelagic sediments increases. The increased role of the pelites is characteristic for the Toarcian to the Middle Jurassic; a high silica content is significant for the upper part of the Middle Jurassic and the base of the Upper Jurassic. The thickness of the sediments is by two orders of magnitude smaller in the Jurassic than in the Triassic. Siliciclastic grains bigger than pelite are completely missing from the Jurassic. The thickness of the Jurassic sequences in the are of continuous sedimentation varies between 40 and 70 metres. Fossils are important in almost every formation and sometimes they are even rock-forming. The most wide-spread fossils are the crinoids, but ammonites, brachiopods, and in some levels also foraminifers, planktonic bivalves, saccocomas, cadosinas and calpionellids abound.

The oldest, the thickest and the most wide-spread formation is the **Pisznice Limestone Formation**. It was deposited on the eroded, notwithstanding smooth surface of the Dachstein Limestone with a hiatus of debated origin. Its most wide-spread fossils are the crinoids that forms lenses of bioturbation origin or even independent beds in the member-rank upper part of the formation. Its most spectacular outcrops are at Tardos (Nagy-Pisznice and Bánya hills) and at Tata (FÜLÖP 1976). The formation is an important element of both continuous and discontinuous sequences.

The **Hierlatz Limestone Formation** in its typical facies is skin-coloured, yellow-brown or light red and mainly consists of calcite-filled dwarf ammonites, brachiopods and crinoid fragments cemented by micritic matrix. VIGH GY. (1935), VIGH G. (1943, in SZENTES 1968) and VÖRÖS (1991) have given a summary of its remarkably rich fossil assemblage. Its most spectacular occurrences are related to the discontinuous areas as fissure fills in the Dachstein and the Pisznice Limestones. The age of this few metre-thick formation is Sinemurian–Pliensbachian (KONDA 1970).

The occurrence of the 1 to 3 metre-thick **Kisgerecse Marl Formation** is restricted to the areas of continuous sedimentation. The formation is a red marl with small nodules of limestones and calcareous marls. Its most common fossils are the ammonites (FÜLÖP 1976). The age is Toarcian. As a rare exception compact, light red ammonite-bearing limestone can be found on the highs as heteropic facies of the Kisgerecse Marl Formation (VIGH G. in SZENTES 1968, FÜLÖP 1976).

The **Tölgyhát Limestone Formation** is similar to the Kisgerecse Marl but it has a slightly increased carbonate content and larger size of nodules. It is confined to the areas of continuous sedimentation. The thickness is 3 to 10 m in this area and the age ranges from Aalenian to Bathonian. Upwards in the sequence the amount of the tiny planktonic bivalves increases that may forming thicker plates or thinner banks while enriched in rock forming quantity. In certain sequences the frequency of these banks increases to such an extent that the formation can be qualified as Tölgyhát–Eplény Formation or even Eplény Limestone Formation. This latter is light red or light grey with chert lenses or beds of radiolarian origin. Both the benthonic and the nektonic forms are missing from it.

The **Lókút Radiolarite Formation** of 1–10 m in thickness overlies the formations above mainly with gaps. Red and yellow clay sometimes more than 1 m thick can be found at the base of the formation. It can also be developed gradually from the underlying formations. The radiolarite in the Gerecse Mountains consists of 5 to 15 cm thick red or black silica beds in which one (Margit-tetõ) or several (Tardos) limestone beds of micritic texture can be intercalated. Chert beds alternate with radiolarian marls on the Nagy-Kõszikla at Kesztölc. Although this formation is considered to be a typical basinal facies, in some cases (Hosszú-vontató and Kis-Somlyó in the Gerecse) this is the first sediment on the highs after a long time interval.

The Lókút Radiolarite is capped by a maximum 1 metre thick red and white breccia bed which is already a member rank basal unit of the **Pálihálás Limestone Formation** of ammonitico rosso facies. It appears mainly in the areas of continuous sedimentation but is often found on the highs as the first sediment after the mid-Jurassic gap. In this latter case the rock is platy rather than nodular. Saccocoma and coarse-grained crinoid fragments are characteristic for the formation. Breccia lenses of debris flow origin are exposed in the Tûzkõ Hill situated at the western foot of the Gorba High at Szomód in the West Gerecse. In both the matrix and the rock fragments green algae (Clypeina) have been documented, indicating shallow platform conditions. The age is Oxfordian–Early Tithonian, the thickness is 1 or 2 m.

The type locality of the **Szentivánhegy Limestone** is the Kálvária Hill, Tata (FÜLÖP 1976). It is well-bedded or platy, light-red, pink or white with micritic matrix. A coarse-grained crinoidal, brachiopod-bearing version ("Hierlatz — Tithonian") is known to occur on the Szél Hill, Tardos at the bottom of the east slope of the Gorba High. Eastwards from the high the sequence is articulated by lens-shaped intercalations of ammonite and crinoid fragments. From its very rich microfossil assemblage the calpionellids are the most important. On their basis the formation can be subdivided into zones of tens of centimetres or even centimetres in thickness. In the East Gerecse the limestone packet of 1–2 m in thickness as a maximum was succeeded by siliciclastic sediments already in the Berriasian whereas the topmost limestone bed at Tata belongs to the Valanginian (FÜLÖP 1976).

Cretaceous

In the Transdanubian Range Cretaceous formations appear only in the central part of its synclinal structure. This axial zone in the Vértes Foreland is oriented in a north-eastern–south-western direction, then turns northerly at Tatabánya and finally to the east in the Gerecse Mountains.

The **Bersek Marl Formation** is only known from the East Gerecse. It is dominated by siltstone and marl with intercalations of turbiditic sandstone beds, and plates of pelagic limestones. The colour of the formation is mainly grey, except for the base and the upper part that are purple-red. It is rich in ammonite casts and aptychi (FÜLÖP 1958, CSÁSZÁR 1995). The Felsõvadács Breccia Member is located near its base. In addition to the prevailing fragments of Dachstein Limestone, it contains Jurassic cherts, limestone with calcareous algae from the Upper Jurassic–Lower Cretaceous and also weathered basic and ultrabasic magmatites reworked from the obducted oceanic basement. The thickness of this member is several metres to the east of the Gorba High while only 10 cm thick bed is known to the west of the high.

The 100 to 200 metre-thick Bersek Marl as the frequency of sandstone banks is increasing upwards. It gradually passes to the **Lábatlan Sandstone Formation** which is basically made up of this rock type. On the top of the formation (Köszörûkõbánya Conglomerate Member) independent breccia-conglomerate banks occur. The significance of the member is that the breccia conglomerate is basically made up of cherts of the Lókút Radiolarite. The rudistid limestone breccias and cobbles with corals and other fossils are also concentrated here. The age of the formation ranges from Valanginian to Albian. It can attain a thickness of 500 metres. The Lábatlan Sandstone and the Tata Limestone interfinger westwards. On the basis of heavy mineral content dominated by chrome spinel B. ÁRGYELÁN (1995) indicated the one-time oceanic basement as its source area.

The only two surface outcrops of the **Tata Limestone** ranged to the uppermost Aptian and Lower Albian are at Tata and Vértessomló, north-west of the Vértes Mountains. The wellbedded or platy limestone is mainly made up of fragmented crinoid skeletons but sea urchin fragments, siliceous sponge spicules, red algae, benthonic and planktonic foraminifers are common (FÜLÖP 1976, CSÁSZÁR 1995). The formation overlies limestone varieties of different Jurassic horizons encrusted deep water stromatoliths indicating a long-lasting submarine non-sedimentation episode.

In the DANREG area no outcrops sedimentary Cretaceous formations younger than the Tata Limestone are known.

Cenozoic

Eocene

Since none of the DANREG maps deals exclusively with the Eocene, Oligocene and Miocene formations in the following some information will be given about those formations that are not present on the surface.

The formations belonging to the Eocene sedimentary cycle resemble those of the previous two geological cycles (Middle and Upper Cretaceous), the products of which are out of the DANREG map sheet. At the same time there is a significant difference between the geographical extent of their sediments: the Eocene ones have been deposited on a surface dissected by troughs, highs and shallow basins respectively during a period of transgression. In the basins and troughs separated from each other at least partially by terrestrial and swampy sedimentation started in the Middle Eocene. This was followed by marly sediments of the invading sea. Simultaneously on the highs limestones, rich in larger foraminifers were deposited. The Middle Eocene transgression is winded at the Buda Line defined as a major structural line by BÁLDI & NAGYMAROSY (1976) and resulted in brackish water clastic sediments again in the Dorog Basin. The Buda Line was interpreted by FODOR (1994) as a buried overthrust that acted as a facies boundary from time to time during the Eocene and Oligocene.

The **Gánt Bauxite Formation** is considered to be the oldest formation of the Eocene. Its age can only be judged by the facts that its overlying formation in the Csordakút–Nagyegyháza Basin is Middle Eocene or at Naszály Upper Eocene. According to B. BERNHARDT (personal communnication) the formation filling up traps developed on the karsted surface of the Triassic is made up of bauxite, extra- and intraclastic bauxites and also bauxitic and kaolinic clays. Its most important occurrences heve been reported from the South Gerecse, mainly in covered form. Its occurrences in the Buda Hills are characterised by high thorium content.

The infilling of the basin started in the Middle Eocene with the **Dorog Formation**, that is according to BERNHARDT a fluvial, lacustrine and paludial sediment. This is a rock body built up by variegated and grey clays, sand, pebbles, freshwater limestones and brown coal beds. Its thickness is a few tens of metres. The coal measures being one of the most important reserve of Hungary are in the upper part of the formation. The number of such measures is two in the Oroszlány Basin and 2 to 4 at other places. Mining activity for shorter or longer period was and is going on in: the Oroszlány, Tatabánya, Dorog, Csordakút, Nagyegyháza, Mány and the Nagykovácsi basins. In the lower part of the formation in the South Gerecse basins the fanglomerate intercalated by bauxite lenses is distinguished as a member-rank unit. The fanglomerate may be up to one hundred metres thick.

The **Csernye Formation** has no outcrop on the territory of the map sheet. According to BERNHARDT's definition this shallow marine formation consists of grey marl, calcareous marl, siltstone and sandstone in which coquina-like enrichments of bivalve and gastropod remains are found sometimes with solitary corals. It is 10 to 50 metres thick.

The **Csolnok Clay Marl** is a formation extending from the shallow-marine to the deep neritic facies. According to BERNHARDT's definition it is a rock body composed of grey clay-marl and marl with a maximum thickness of 100 metres. The formation is characterized by larger foraminifers (Operculina, Nummulites, Discocyclina, Actinocyclina and Assilina) in rock-forming quantity. The formation has outcrops in the North Gerecse, in the Dorog Basin and on the north-eastern edge of the Tatabánya Basin.

The **Szõc Limestone Formation** of shallow sublittoral and littoral facies is the characteristic formation of the highs and the edges of the basins. Its thickness varies in extremely but in the relevant area it rarely goes beyond 50 metres. The limestone is usually well-bedded or platy, as a rule nodular and argillaceous in structure. It contains Nummulites —first of all *N. perforatus* and *N. millecaput*— and other larger foraminifers as it is one of the most fossiliferous formations in Hungary. Of the three members of the formation the lower one is formed by biodetrital limestone. It is followed by a unit characterized by the massive presence of *N. perforatus*, and capped by the *N. millecaput* and Discocyclina-bearing units.

The **Tokod Formation** is of transitional character between the marine and freshwater environments. It is the first sign of the regression that was taking place in the Transdanubian Range about the end of the Middle Eocene. The lithological composition, according to BERNHARDT & KNAUER [in CSÁSZÁR (ed.) 1997] varies between marine and brackish-water molluscan, nummulitic and miliolina-bearing clay-marl, marl, freshwater limestone and calcareous marl, and fluvial sand and calcareous sandstone. Its thickness ranges from 10 to 60 metres. The formation can be traced from the Tatabánya Basin as far as the Buda Hills in surface outcrops too.

The **Lencsehegy Formation** of paludial and fluvial facies is a product of the utmost regression at the end of the Middle Eocene. According to BERNHARDT (1997) it consists of an alternation of grey sand, sandstone, carbonaceous clay and brown coal. The extent of the 10 to 60 metres thick formation is restricted to the Dorog and Mány basins and the Buda Hills.

The extent of the **Kosd Formation**, according to BERNHARDT's original definition [in CSÁSZÁR (ed.) 1997] is restricted to the area of the Danube East Side Horst blocks. This terrestrial, fresh-water and on its top brackish-water formation is identified with the mixed sequence of variegated and grey clays, bauxitic clays, sand, gravel, dolomite and limestone fragments, molluscan marl, freshwater limestone and brown coal at the base of the Eocene located south-east of the “Buda Line”.

The Upper Eocene **Szépvölgy Limestone Formation** is a product of a new transgression subsequent to the Middle Eocene regression. It overlies on Triassic formations in the zone of the “Buda Line” in the Buda Hills with rock fragments at the base. The formation, according to BERNHARDT [in CSÁSZÁR (ed.) 1997] is a light grey rock body of biogenic limestones and calcareous marls with preponderance of Nummulites and Discocyclina species and Lithothamnium colonies. Sand and conglomerate beds are also included in the formation in the Dorog Basin and at the northern part of the Gerecse Mountains.

The **Buda Marl Formation** (FODOR *et al.* 1994) spreading across from the Upper Eocene to the Lower Oligocene is an eloquent testimony for the role of the facies separation along the “Buda Line” as this formation only appears on its south-eastern side. The Buda Marl is composed of marl and calcareous marl in the lower part and mainly of clay-marl in the upper part. The latter one also contains intercalations of tuffites, tuffitic sandstones and allopadic limestones indicating an increasing deepening towards the south-east.

At the end of the Eocene the larger part of the Transdanubian Range emerged over the see level and an important but irregular erosion started (“infra-Oligocene denudation”).

Oligocene

The new sedimentary cycle shows a fundamental change in the character of sedimentation. The period from the Triassic to the end of the Eocene was characterized by the preponderance, or at least an equal weight of carbonate sedimentation. In the Oligocene and in the subsequent periods the clastic sediments played an exclusive (in the Miocene only dominant) role. Relatively close to the “Buda Line” in south-eastern direction the sedimentation was continuous. There the Buda Marl was replaced by the Tard Clay Formation gradually (BÁLDI 1983).

The anoxic shallow bathial **Tard Clay**, according to NAGYMAROSY [in CSÁSZÁR (ed.) 1997], is a dark-grey, laminated, clayey siltstone with frequent bioturbation in its lower part, and tuffite and sandstone intercalations in the middle part. The formation has a few outcrops on the eastern margin of the map only.

The **Kiscell Clay Formation** south-east of the “Buda Line” has great thickness up to 1000 metres. West of the “Buda Line” as far as the western margin of the Dorog Basin some formations of a few tens of metres in thickness can be ranged also to this unit. According to NAGYMAROSY [in CSÁSZÁR (ed.) 1997] the formation is light-grey clayey, calcareous siltstone with fine grained sandstone intercalations in the lower part (Budakeszi Member). In the remote areas off the eastern margin of the map the formation contains gravely fluxoturbidite intercalations.

According to BÁLDI (1983) and NAGYMAROSY & BÁLDI-BEKE (1988) the base of the **Hárshegy Sandstone Formation** and the uppermost beds of the Tard Clay are coeval, that is the Hárshegy Sandstone is in part heteropic facies of the Kiscell Clay, too. According to NAGYMAROSY's definition [in CSÁSZÁR (ed.) 1997] the Hárshegy Sandstone is mainly coarse-grained sediment, here and there with conglomerate, fire-clay and brown coal beds. It is mainly a littoral and shallow sublittoral formation with brackish-water beds in its lower part and kaolinitic sandstones in its upper half. The interval with brown coal measures is distinguished as the Esztergom Coal Member. The rocks of the formation along the “Buda Line” are cemented by silica, chalcedony or barite of hydrothermal origin (KORPÁS 1981). The thickness of the formation ranges from 20 to 200 metres. Apart from that part of the formation which is cemented by silica the correct distinction of the formation from the neighbouring

Mány and Törökbálint Formation has not been made. Therefore the extent of the formation shown on the map is only one of the options.

Although the Mány Formation and the **Törökbálint Sandstone Formation** are independent lithostratigraphic units, the previous geological mapping and descriptions do not make their distinction possible. Therefore on our map they appear as a joint single key element. According to NAGYMAROSY [in CSÁSZÁR (ed.) 1997] the Törökbálint Formation consists of coarse and fine grained sandstone beds with clay (Solymár Member) or conglomerate intercalations in its lower part and siltstone beds in the upper one. The formation has been deposited in a shallow sublittoral environment with brackish water influences in the upper part. The formation is known to occur from the Gerecse Mountains as far as the Cserhát Hills in a thickness of 200 to 500 metres.

According to NAGYMAROSY [in CSÁSZÁR (ed.) 1997] the **Mány Formation** is an alternation of calcareous and clayey silt, siltstone, sand and sandstone into which conglomerates, thin lignite seams and variegated clay beds intercalate. It is basically a brackish-water lagoon deposit but it has also freshwater and normal marine intercalations and even a lignite seam in the basal part. The estimated thickness is 200 to 600 metres.

The Oligocene/Miocene boundary usually does not coincide with the boundaries of the formations but there are several formations within which the chronostratigraphic boundary is drawn. One of them is the **Becske Formation** which is represented on the surface only by a few outcrops at the eastern rim of the Börzsöny Mountains where its westernmost subsurface occurrences are restricted. Its thickness is ca 100 metres there. The Becske Formation is a brackish-water paludial and fluvial sediment with marine interlayers. It consists of pelitic fine-grained sandstones in the lower part, lignitic siltstone in the middle, and fluvial, pebbly sand and sandy gravel in the upper part [HÁMOR & NAGYMAROSY in CSÁSZÁR (ed.) 1997].

The **Pétervására Sandstone** and the **Szécsény Schlier Formations** are typical formations in North Hungary. Many of the surface outcrops indicated as undivided Oligocene may be ranged into these formations. The latter one does not have any identified outcrop within the frame of the map sheet. However, among the numerous undivided Oligocene–Miocene outcrops a few may belong to it. Its subsurface presence on the Pest Plain is very probable. This deep sublittoral and shallow bathyal, open marine formation comprises grey, greenish-grey, sandy, micaceous, clayey siltstone and clay-marl in which sandstone intercalations also occur. In the upper part molluscan coquinas are common. The thickness of the formation can attain some tens or some hundreds of metres.

The **Csatka Formation**, the third Oligocene–(?Miocene) formation, in contrast to the previous ones is characteristic for the Transdanubian Range. It has outcrops in the western foreland of the Vértes and the Gerecse Mountains. According to KORPÁS (1981) the formation is a cyclic fluvial flood plain and channel sediment with smaller lacustrine and paludial lenses in its lower and middle part. These are distinguished as the Szápár and Noszlop Members. Its most wide-spread formation is the variegated clay but the greenish-grey clay and clay-marl, gravel and conglomerate, sand and sandstone beds respectively are common, too. On the surface the latter seem to be the most significant. In spite of the subsequent overall erosion (no continuous overlying is known) its thickness can reach 800 metres even today. The sedimentary cycle in the western part of the Vértes and Gerecse mountains starts with the Csatka Formation and gradually or with interfingering of facies passes into the Mány Formation. A similar relation may be supposed between the Mány and the Törökbálint Formations somewhere in the western foreland of the Buda Hills and the Pilis Mountains. It is also clear from the above mentioned that moving from south-west to north-east direction, there is a regular trend in facies change. The sedimentary environment in the south-west is exclusively fluvial channel and flood plain; this is replaced first by brackish-water and then by shallow marine basinal environment, and east of the "Buda Line" a deepening and rapidly subsiding basin developed.

Miocene

The extent of the Miocene formations testifies to basic changes in the structural history of the area. The Mesozoic and the Palaeogene sedimentation history was governed basically by the structural pattern outlined at the beginning. The new structural arrangement developed by the beginning of the Miocene highly resembles the present-day one. The products of the new sedimentary cycle were deposited for the first time overlappingly on the basic structural units and the fundamental tectonic zones (*e.g.* the Rába Line) separating them. Although Miocene sediments are found also in the inner basins of the Transdanubian Range, the main point of the sedimentation was shifted to the basins developed apart the Transdanubian Range, among others to the Kisalföld. Concerning our area the only exception is the North Hungarian Range where the Palaeogene basin continued acting during the Miocene too.

The overview of the Miocene formations will be given according to their temporal succession regardless of their geographic distribution.

According to BÁLDI & BÁLDI-BEKE (1985) the **Budafok Sand Formation** ranked to the Eggenburgian stage does not go beyond the Buda Line westwards. On the present map, on the contrary, some occurrences are considered as part of this formation nearby Visegrád as the north-western most outcrop, and also in the northern foreland of the Börzsöny Mountains. The formation, according to HÁMOR in [CSÁSZÁR (ed.) 1997], consists of yellow and grey sandstones into which gravel and clay intercalate. In certain levels it involves Pecten, Ostrea and Anomina coquinas in great quantities.

The **Brennberg Lignite Formation** of freshwater to paludial facies belongs to the Ottnangian stage. According to HÁMOR in [CSÁSZÁR (ed.) 1997], it is made up bylignite measures with unsorted coarse-grained rock fragments at the base, and of grey, clayey sand beds above lignite-bearing member. Up to now the formation has been known from the environs of Sopron only, where its maximum thickness is 180 m.

The **Gyulakeszi Rhyolite Tuff Formation** also belongs to the Ottnangian stage. It is described by HÁMOR [in CSÁSZÁR (ed.) 1997] as greyish-white, thick-bedded, biotitic, pumiceous and often ignimbritized rhyolitic and rhyodacitic flood tuffs. The tuff was often deposited on dry land. Owing to its small local thickness (up to a few tens of metres) it is not distinguished as an independent patch on the map.

The **Ligeterdõ Gravel Formation** is a characteristic formation of the Sopron area and the western part of the Kisalföld. According to IVANCSICS [in CSÁSZÁR (ed.) 1997], this is a sediment of mainly fluvial and subordinately brackish-water origin that consists of badly sorted gravel and conglomerate, just as sand and marl beds. The lower beds with prevailing metamorphic pebbles and conglomerates are distinguished as the Alsóligeterdõ Member while the subsequent bundles of beds as the Felsõligeterdõ Member. This latter one in addition to metamorphic rocks includes carbonate pebbles as well. The middle part of the formation with lignite strings and Congeria-bearing beds is called as Magasbérc Sand Member. The formation is capped with gravel and conglomerate beds of the Felsõtödl Gravel Member. The thickness of the formation of the Ottnangian and Carpathian ages may attain 500 metres.

The extent of the **Egyházasgerge Formation** belonging to the Carpathian stage according to HÁMOR [in CSÁSZÁR (ed.) 1997], is restricted to the North Hungarian Range. On the present map, in addition to some East Börzsöny occurrences the eastern part of the Visegrád Mts also contains outcrops ranked here. The formation consists of cross-bedded sand and sandstone beds of coastal facies. In some places it is introduced by basal conglomerate or gravel. The formation known also as the “Chlamys sandstone” or the “little-Pecten beds” has intercalations of estuary character (Congeria, Oncophora and Paphia beds). Its thickness is 30 to 100 m.

According to HÁMOR's interpretation [in CSÁSZÁR (ed.) 1997], the **Garáb Schlier Formation** in addition to the type area (North Hungarian Range) occurs also in the Transdanubian Range. This cyclic offshore formation is composed of grey, often micaceous sand, silt, clay and clay marl with species of Amussium, Tellina, Brissopsis and other mollusc genera. The formation is featured by slumps, trace fossils and also resedimented tuffite stripes. The thickness of the formation ranged to the Karpathian stage is ca 600 m.

The **Fót Formation** is an other particular formation of the Karpathian stage. Occurs in a few smaller or larger patches on the eastern side of the Danube on the relevant map. The formation is composed of bryozoan and balanus-bearing calcarenite, as well as gravelly sandstone and sand with limy concretions varied by gypsiferous clay and upwards increasing frequency of pyroclastics. The thickness is about 50–70 m.

One of the far-traceable products of the intensified volcanic activity in the Karpathian age is the **Tar Dacitic Tuff Formation**. According to HÁMOR's definition [in CSÁSZÁR (ed.) 1997], it is a light-grey, biotitic, pumiceous dacitic tuff and tuffite. Deriving from the rock type of the formation its host rock is of varied lithology and origin. The 15 to 30 m thick formation is referred to in the earlier literature as the “middle rhyolitic tuff”.

The **Perbál Formation** qualified as Karpathian–Badenian in age is built up by alternating terrestrial pied clay, silt and sandstone with tuff and tuffite intercalations [HÁMOR in CSÁSZÁR (ed.) 1997]. It is not figured in the present map as independent patches.

The most spectacular products of the Miocene volcanic activity generally occur on the surface in the Börzsöny and Visegrád Mountains. According to the present valid lithostratigraphic division almost all volcanic rock types in the map are ranked to the **Mátra Andesite Formation**. According to HÁMOR's definition [in CSÁSZÁR (ed.) 1997] the Mátra Andesite, appearing as a stratovolcano is made up mainly of amphibole-andesite and its pyroclastics and in the upper part of the formation of pyroxene-andesite. Dacites and rhyolites are also present at the **adventive craters** of the larger volcanic centres. In spite of the fact that certain outcrops proved to be undividable, M. DARIDA-TICHY distinguished 11 informal subunits as key elements within the formation. Most of these are subvolcanic bodies that can be distinguished from each other by their distinctive mineral components. In addition to this, she also identified the undividable pyroclastics, the larger lava bodies and the stratovolcanic sequences as separate elements. On the basis of the above mentioned a further lithostratigraphic subdivision of the Mátra Andesite is a question to be considered.

The **Baden Clay Formation** ranked to the Badenian stage does not occur on the surface in the map sheet. However, on the basis of the data obtained from hydrocarbon exploratory wells it can be stated that it is a characteristic formation of the Kisalföld Basin. This relatively uniform formation consists of grey, greenish-grey clay and clay-marl beds rich in molluscs and foraminifers. Its thickness may be close to 1000 m. The formation is underlain by lithostratigraphically unidentifiable rock fragments.

The grey, foraminifer-bearing clay-marl, called **Szilágy Clay Marl Formation** by HÁMOR [in CSÁSZÁR (ed.) 1997], is of shallow basin origin and also ranked to the Badenian. The Turritella- and Corbula-bearing formation with sandstone and tuff stripes seems to be interfingering with the Rákos Limestone Formation. In the Börzsöny area there are outcrops believed to be rankable here. Its thickness does not exceed 100 m.

The **Rákos Limestone Formation** of patch-reef environment is the most fossiliferous Miocene formation. It consists of lithothamnium limestone, molluscan limestone and calcarenite. The rock body which at some places has conglomerate at its base has excellent outcrops in the

Sopron Hills, but a few outcrops are known also from the Börzsöny and the Visegrád Mountains. Its presence in larger extent is probable in the Kisalföld sequence too.

The **Galgavölgy Rhyolite Tuff Formation** is a pyroclastic lithostratigraphical unit of the largest geographic extent. It is made up of grey, biotitic, pumiceous rhyolitic-tuff, occasionally of dacite and andesite and rock fragments as well. It came into being under terrestrial circumstances in ignimbritized form too and in fresh- or brackish-water environment of graded character. Its outcrops on the territory of the present map are known only from the Börzsöny Mountains, but underground it can found also in the sequences of the Kisalföld. Its total thickness is less than 30 m.

The **Budajenõ Formation** ranked to the Sarmatian has no outcrop. The formation deposited in a drying-out brackish-water lagoon is composed of platy silt and silty clay-marl, including small dolomite, sulphur, gypsum and anhydrite beds [Hámor in Császár (ed.) 1997]. It was proved on the territory of the map sheet only underground, in the Zsámbék Basin (borehole Budajenõ Bö–2).

The **Kozárd Formation** of shallow brackish-water coastal facies with no outcrops on the territory of the map sheet is rich in molluscan coquinas [Hámor in Császár (ed.)1997]. However, the clay and clay-marl beds of 100 to 150 m thickness greenish-grey and grey sand, sandstone and calcareous marl intercalations are common in the sequences of the Kisalföld.

Out of the Miocene formations the **Tinnye Formation** has the biggest outcrops on the map sheet, namely in the Zsámbék Basin. According to Hámor [in Császár (ed.) 1997] it is a yellow rock body composed of casts of molluscs, ooidic calcarenite and sometimes of mollusc sand. Its version deposited on older basement often starts with basal gravel. In the earlier literature it is called “Sarmatian rough limestone”. Three members of the Tinnye Formation have been distinguished by J. Ivancsics in the Sopron Hills that are probably distinguishable in some successions of the Kisalföld as well. The total thickness of the formation is cca 100 m. It is indicated in the map together with the Perbál Formation.

Thanks to the well Pásztori–2 it became obvious that the volcanism outlined by the magnetic data in the Kisalföld represents a time interval starting in the Badenian and continuing in the Pannonian (13.3–8.6 Ma) and that the volcanic matter is of trachytic composition. According to Németh & Hámor's definition [in Gyalog (ed.) 1996] the formation is an irregular alternation of conglomerate, tuff and marl.

Pannonian

The distribution, facies relations and the thickness of the formation ranked to the Pannonian stage are shown in separate maps that are explained in an independent chapter. Therefore in this chapter only the basic features of the Pannonian sequence are briefly outlined.

The change taken place in the area of sedimentation at the beginning of the Miocene was consolidated in the Pannonian and the subsidence of the Kisalföld was accelerated. The Pannonian sequence developed gradually from the Sarmatian formations, mainly from the Tinnye Formation in the deepest parts of the basin areas and with basal rock fragments along the current basin margin (Jámbor 1980). The Lower Pannonian sediments of decreasing salinity of the Pannonian Sea (Korpás-Hódi 1983) surrounding the Transdanubian Range, can also be found in the embayments of the range. The most important embayment indicated also on the map is the Zsámbék Basin. The marl and clay-marl are the prevailing rock types in the Lower Pannonian formations but sandstone intercalations are also found. The Upper Pannonian stage is characterized by rock bodies of delta facies dominated by sandstone beds. In the uppermost part of the sequence drying-out paludial conditions developed on large areas, the products of which are both carbonaceous and variegated clays. These sediments are unambiguous evidences of the filling-up of the basin. The Upper Pannonian formations are proved to go beyond the Lower Pannonian sediments in the north-western part of the Gerecse Mountains, while in other areas because of the subsequent erosion this can only be supposed.

Quaternary

The genetic subdivision, the surface distribution and the global thickness of the Quaternary formations are dealt with in an independent map. Its explanatory notes summarize the Quaternary geology of the map sheet in a separate chapter. Therefore only the basic features of the Quaternary will be outlined here.

The Kisalföld Basin was filled in by the end of the Pannonian but the fluvial sedimentation was continuing west of Gyõr during the Pleistocene with coarser and coarser sediments. (More details are given under the subheading: Quaternary of the Danube Lowland.) In other areas the sedimentation was replaced by erosion, and any further sedimentation took place only occasionally and under special circumstances. The Quarternary sequence is subdivided into 10 chronostratigraphic units by the authors. Within each unit the following basic genetic groups can be found: fluvial, lacustrine, paludal, peatbog, proluvial, deluvial, terrace, spring-water and aeolian. In order to reflect all combinations of the depositional environments a great variety of the above mentioned genetic units are distinguished. The lithological composition in most of the above mentioned genetic cathegories may vary between broad limits. The catgories created this way, that is the number of the Quaternary elements of the legend is close to 70. In the flat areas are found mainly formations ranked to the fluvial, terrace, lacustrine, paludal and peatbog environments whereas in the hilly and mountainous areas aeolian, proluvial, deluvial, eluvial, spring-water and terrace sediments are significant. Of course, aeolian sediments are not rare on the lowland areas either but they are often mixed or resedimented in wet systems. A symbol, representing the consequences of the altering activities of the human being is also attached to the Holocene part of the legend.

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