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Map of the pre-Tertiary Basement

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Introduction

This map and its explanatory notes are the result of unified Austrian [G. WESSELY, A. KRÖLL, R. JIØIÈEK, F., NEMECZ (WESSELY *et al.* 1993)], Slovak (J. VOZÁR) and Hungarian (G. CSÁSZÁR) contributions. As the major part of the map area is covered by Tertiary sediments, the content of the map is mainly based upon dates from boreholes and geophysical measurements.

The map user must be aware of the fact that the map content is not homogeneous in various respects:

— According to the subtitle of the map the pre-Tertiary basement is extended to Palaeogene elements in the Alpine-Carpathian belt (Laab Nappe, Gosau Group).

— The Alpine Carpathian Belt is subdivided mainly into tectonic units whereas the Pelso Unit in the south-eastern part of the map is represented by a succession of lithostratigraphic units.

— Unequal reliability of the map content depending on both the depth of the basement surface as well as the density of borehole data.

The following explanations present separately two fundamental thematic aspects of the pre-Tertiary basement map:

— the relief of the basement surface and,

— the internal structure and lithology of the basement.

As the basement relief is directly connected with the subsidence or uplift of fault-bounded basement blocks there is, of course, a close genetic relation between this relief and the internal structure of the basement.

Relief of the basement surface

The relief of the basement surface is indicated in the map by isolines and a stepwise shading. The measures of the isolines are related to sea level. The space between the 0 m and –1000 m levels is subdivided into 200 m intervals, below the –1000 m level into 500 m intervals. In addition each 2500 m interval below the 0 m level is marked with a shading stepwise increasing in density towards the depth. Because of the scale and the thematic content of the map the surface outcrops are not delineated.

From W to E the relief of the basement is subdivided into

— the SE part of the Vienna Basin,

— the high zone of the Sopron Hills, the Leitha Mts and the Malé Karpaty Mountains,

— the Little Pannonian Basin (Podunajská panva in SW Slovakia, Kisalföld in Hungary) and

— the high zone of the Transdanubian Range.

Within the DANREG sector of the **Vienna Basin** several local depressions (Schwechat, Mitterndorf, Marchfeld, Lassee) and high zones (Aderklaa–Matzen, Enzersdorf, Zwerndorf–Vysoka) can be distinguished, generated mainly by NE–SW striking faults or fault systems. The grabens of Mitterndorf and Lassee are situated along the eastern flank of the Vienna Basin which is bounded in the SE by the marginal faults of the Engelhartstetten–Kopfstetten fault system. The extension of the mentioned graben has been interacting with a sinistral strike-slip faulting which is active until recent times.

The Vienna Basin can be interpreted as an area of extension and subsidence at the beginning of the Miocene, when the Alpine–Carpathian Nappe system moved towards N and the Carpathian Nappe system had to turn anticlockwise around the SE corner of the Bohemian Massif. Maximum subsidence occurred during Middle Miocene time. Vertical displacements outside the DANREG sector of the Vienna Basin attained measures of 4000 m to 6000 m. Similar figures were attained by sedimentary accumulations during the Miocene (*e.g.* in the Schwechat Depression).

NW–SE striking structures might have more importance than so far known and have been proved within the Vienna Basin and the adjacent high zones in the SE according to evaluations of the horizontal gradient of the Bouguer anomaly (KRÖLL *et al.* 1993, Plates 2 and 3).

Along the high zone constituted by the Sopron Hills, the Leitha Mountains and the Malé Karpaty Mountains (Little Carpathians) the basement is partly exposed at the surface. Besides the cross structures near Sopron also the morphological saddle structure in the area of Bruck an der Leitha (Brucker Pforte) might have some genetic relation to the previously mentioned NW–SE faulting.

Towards SE the great depression of the Little Pannonian Basin is introduced by several NE–SW striking faults. In the Slovak part the dominant fault of this character is the Malé Karpaty Fault, which is distinctly separating the exposed Tatric part of the Malé Karpaty Mountains from the Tertiary–Quaternary filling of the Danube Basin [MAHEL' (ed.) 1972; FUSÁN *et al.* 1987; BIELY *et al.* 1996].

Within the depression of the Little Pannonian Basin dissected mainly by several NE–SW directed faults, several high zones, troughs, basins and branches can be distinguished. In the northern Slovak territory lies the Trnava Basin, in the centre the Gabèíkovo/Gyõr Basin, in the east the Komjatice and ≥eliezovce depressions (VASS *et al.* 1988) are to be found. In the Hungarian part the morphology of the deep basin was first outlined by VAJK R. (1943) with support of geophysical measurements. The deepest part of the basin that exceeds 8000 metres below the sea level is located east of Ásványráró village. The area, also known as the Gyõr Basin is separated from the Kenyeri Basin by a smaller high of NW–SE direction. Other morphological features are the Mihályi High and the Csapod through W of the Kenyeri Basin.

Without any significant faulting the basement surface gradually rises towards the Transdanubian Range in the East as far as the Császár–Szend High. From here towards E buried troughs and highs of NNE–SSW direction are alternating as far as the Tatabánya Basin, farther on N–S, later NNW–SSE oriented hills, outcrop-lines and trough-shaped basins follow each other.

Structure and lithology of the basement

The basement of the DANREG area can be subdivided into two major units: the Alpine–Carpathian belt in the western and northern part and the Pelso Megaunit [in the *sense* of FÜLÖP & DANK (eds) 1987] of the Transdanubian Range in the south-eastern part.

The two units are separated from each other by the Rába–Hurbanovo Fault zone (VOZÁR *et al.* 1994, VOZÁR 1996) which is an important transform fault zone known from seismic and magnetotelluric measurements. The Rába Zone s. str. (Rába Line — SCHEFFER & KÁNTÁS 1949) is oriented NE–SW. Its eastern continuation, the Hurbanovo Zone, runs E–W and continues into the Diósjenõ Line.

Position, orientation and character of the Rába Zone are a point of much debate. Based on seismic measurements its south-western part is located beyond the border of the map on the Ikervár High (MATTICK *et al.* 1996) where the Sót–1 well certifies the overthrust of the Pelso Unit above the Central Alpine Unit. This statement is supported by the regular SE dip of a metavolcanic intercalation within the metamorphites at Ikervár.

Alpine–Carpathian Belt

As mentioned above its subdivisions in the map are mainly of tectonic nature. The order of description follows the order of the legend.

Penninicum

Flysch Zone. In the utmost NW corner of the map a small triangle of the Rhenodanubian Flysch Zone is situated represented here by mainly Upper Palaeogene sedimentary rocks of the Laab Formation. In terms of regional tectonic units it belongs to the Penninicum and occupies the deepest tectonic position in the Alpine–Carpathian Belt of the DANREG area (ELIAS *et al.* 1990).

The central part of the Gabèíkovo Depression consists of ultramaphic rocks and their metamorphites according to J. VOZÁR. This interpretation is based on geophysical data, mainly on results of aerborne (GNOJEK 1993) and terrestrial magnetic surveys (GNOJEK & KUBES 1991, SEIBERL *et al.* 1994, for purposes of the DANREG programme). We correlate this identified unit here (VOZÁROVÁ & VOZÁR 1996) with occurrences of the Southern Penninicum in the Kõszeg area of Hungary [FÜLÖP & DANK (eds.) 1986] and with the area of the Rechnitz tectonic window in Austria (KOLLER & PAHR 1980; KOLLER & WIESENEDER 1981; PAHR 1983). The magnetic anomaly of the Gabèíkovo depression is explained two-dimensionally by KUBES *et al.* (1989). This would imply that in its structure two sources take part, from which the deeper (8 km) belongs to the assumed Penninicum and the shallower (about 4 km) to a Badenian volcanic complex.

Low grade metamorphic pelitic–carbonatic and siliciclastic sediments of Jurassic–Cretaceous basin facies and basic to ultramaphic magmatites of an oceanic rift zone are exposed not far beyond the southern edge of the map in the tectonic window of Rechnitz representing the Penninicum. According to G. CSÁSZÁR it continues not only below the Central Alpine Unit but also below the Rába Metamorphite Zone. Also J. VOZÁR assumes a tectonic inlier of Penninicum underlying the Palaeozoic metasediments and metavolcanics of the Mihályi Phyllite Formation (VOZÁR *et al.* 1994, VOZÁROVÁ & VOZÁR 1996).

Upper Austroalpine Unit

Frankenfels Nappe, Lunz Nappe. The Upper Austroalpine Unit which occupies the highest tectonic position follows SE of the Flysch Zone and has overridden it towards NW. Next to the Flysch Zone there is the Frankenfels–Lunz Nappe system, comprising intensely folded and imbricated predominantly carbonatic rocks of Late Triassic to Late Cretaceous age. Anticlines with Hauptdolomit in the core and synclines with the Albian to Lower Cenomanian Losenstein Formation in the axis can be trailed for considerable distances. For example the Höllenstein and the Teufelstein Anticline separated by the Flössel Syncline were identified in the Aderklaa region.

Upper Cretaceous to Palaeogene coarse clastics, marls, shales and sandstones. These rocks above belonging to the Gosau Group and forming the Giesshübl Syncline (total thickness 600 m to 800 m) overlie unconformably the intensely deformed Frankenfels–Lunz Nappe.

The Gosau beds of Glinzendorf overlying the Göll Nappe are mainly of Campanian and Maastrichtian age and may attain 2000 m thickness. The succession is dominated by limnic facies, marine episodes occur in the lower part rather than in the upper one.

Göll Nappe (carbonates; Permian to Upper Cretaceous). The Göll Nappe overlies the Frankenfels–Lunz Nappe exhibiting a less intensely deformed internal structure because of greater thicknesses of the involved Permian to Upper Cretaceous carbonates. South of the frontal Gänserndorf Anticline the formations become gradually flattened. In the area Schönkirchen–Gänserndorf back-thrusting caused by compressive movements has affected the frontal part of the Göll Nappe. The back-thrusted nappe slice is separated into two subslices.

High Limestone Alpine Nappe. The High Limestone Alpine Nappe occupies the highest tectonic position within the Upper Austroalpine Unit. It is built up by Permian to Jurassic, locally by Upper Cretaceous, carbonates. In the area of Baumgarten a deep-reaching syncline has been proved by drilling (Schönfeld T1). Olistoliths recognised in the borehole of Zwerndorf T1 may be explained as parts of major tectonic subslices in the southernmost parts of the High Limestone Alpine Nappe as the result of intra-Jurassic gravity gliding.

Greywacke Zone and Rába Metamorphite Group. The Greywacke Zone is known to be the primary base of the High Limestone Alpine Nappe. It consists of Palaeozoic meta-graywackes, porphyroids, greenschists, and carbonates. The Greywacke Zone is diving towards NW below the High Limestone Alpine Nappe. The Mihályi Phyllite Formation of the Lower Palaeozoic Rába Metamorphite Group is correlated with Graz Palaeozoic Unit. It is adjacent to the Central Alpine Unit in the E and separated from the latter by an westward dipping thrust-plane and is correlated with the Greywacke Zone by both G. Császár and J. Vozár. The zone formed by rocks of low-grade and very low-grade metamorphism is considered by Balázs (1975) and Fülöp (1990) as a prolongation of the Graz Palaeozoic. Concerning the age of the formations the experts, opinions are different due to the insufficiency of palaeontological evidence. The standard Silurian subdivision made by Oravecz (1964) was based on Hystrichosphaeridea. Four of the five formations distinguished within the zone lie beyond the border of the map sheet. One of them is the Szentgotthárd Slate Formation. This in addition to the predominant phyllite also contains calcareous phyllite, sericite-, calcite-, chlorite-schist and sandy slate.

Fülöp (1990) sees the **Nemeskolta Sandstone Formation** as a cycle-beginning formation built up of dark-grey sandstone, subordinately silty slate, chlorite-schist and phyllite. The rock body consisting of neutral and basic rocks of tuff and lava origin was united into the Sótony Metavolcanite Formation by Fülöp (1990) noticing that tuffs are found in the other four formations as well. [The name of this formation in Balázs & Koncz (1987) is Sótony Metabasalt.]

The most detailed information is available about the **Mihályi Phyllite Formation** (Balázs 1971, 1975; Lelkes-Felvári 1982; Árkai & Lelkes-Felvári 1987; Lelkes-Felvári *et al.* 1986, Lelkes-Felvári & Sassi 1983, Lelkes-Felvári 1998; Balla 1994) that is described in details by Fülöp (1990) under the name Mihályi Phyllite. Lithologically it is similar to the Szentgotthárd Phyllite: alternation of phyllite, carbonate-phyllite, quartz-phyllite, quartz-, sericite-, chlorite-phyllite and biotitic albite-phyllite. Therefore Fülöp (1990) was considering to unite these two formations. It is worth mentioning that the carbonate content of the sequence, that includes dolomite, siderite and ankerite as well increases upwards while the frequency of tuff decreases. The Upper Devonian **Bük Dolomite** (Mattick *et al.* 1996) has been encountered in ten wells (Bük–1, –2, –3, Ölbõ–4, –5, –6, Rábasömjén Rás–I, –III, Pecöl Pe–1 and Mihályi M–28) close to the southern border of the map. In addition to microcrystalline dolomite, the formation contains marly slate, quartz–phyllite, sandstone–schist and volcanoclastic rocks, too (Fülöp 1990). The basement formations of the wells Pe–1, Öl–2, –3, –5 and Vt–1 ranked also here were distinguished by (Mattick *et al.* 1996) as the “Ölbõ carbonate-phyllite”.

Based on mineral paragenesis, grade of illite crystallisation and geobarometry on mica bo and radiometry made by Árkai *et al.* (1987), Árkai & Balogh K. (1989), Balla (1994) concluded that no Tertiary metamorphism can be proved in the area, only the Cretaceous one. According to Balla (1993, 1994) these pieces of information also supported his conviction that the Mihályi Phyllite is identical with the metamorphites of the Penninic Unit, just like the Bük Dolomite is identical with the carbonates of the Penninicum. In spite of the great similarity of the different formations of the zone (tuff, carbonate, sandstone intercalations) and the transitional patterns between the Mihályi and Bük Formations, according to Császár, there is no reason to divide the sequence into a Palaeozoic and a Cretaceous sequence. The occurrences of dolomites and ferriferous carbonates of the Mihályi Formation can not be considered typical in the deep water sediments of the Penninicum. According to the seismic measurements the position of the Bük Dolomite above the Penninic formations is a result of an overthrust. The 150–200 metres thick “Ölbõ formation” is considered to lie unconformably on the Bük Dolomite (Mattick *et al.* 1996).

The phyllite and slate presented without any data in a larger proportion of the Rába Metamorphite Group are merely hypothetic. On the basis of the significant gravity anomaly in the deepest part of the basin and the magnetic anomaly west of it can not be excluded that the basement of the basin above the rather thinned crust consists of a rock other than phyllite.

Fülöp (1990) considers the Rába Metamorphite ”sequence” to be imbricated and to have a nappe structure of north-eastern vergency. The speciality of the succession in his figure is that beside the several imbrications or nappes it contains only one fault along which the Bük Dolomite has got into the neighbourhood of the Mihályi Phyllite with a movement of at least 2000 metres. This contradiction could be solved, as it is also suggested by him in the text, if the Bük Dolomite was considered as an intercalation within the Mihályi Formation.

The remaining tectonic units of the Alpine–Carpathian Belt in the basement below the Tertiary are from the top to the bottom as follows: from the Inner Western Carpathians the Silicicum (*sensu* Mello 1979); from the Central Western Carpathians the nappes of the Hronicum (prevailingly Upper Palaeozoic of the Sturec Nappe), the nappes of the Fatricum (KríΩna Nappe *sensu* Andrusov *et al.* 1973), the Southern and Northern Veporicum (*sensu* Vozárová & Vozár 1988) and the Tatricum (*sensu* Andrusov *et al.* 1973), which in the DANREG area are divided into three groups, the Tríbeè, PovaΩsk˝ Inovec and Malé Karpaty groups.

Silicicum

In the north-eastern part of the map the Inner Western Carpathians are represented by the Silicicum. The Mesozoic is preserved at the surface in the so called “Levice Islands” (Biely 1965). On the basis of the study of borehole profiles from the substratum of Neogene volcanites this Mesozoic was considered as part of the Muráò or Gemeric Mesozoic (Vozár 1969) correlated with the Drienka Unit (*sensu* Bystrick″ 1964). Later Biely (1977) ranged this Mesozoic to the Silica Nappe, so actually not changing the conception of the position of the Mesozoic as nappe unit of the Inner Western Carpathians when compared with the views quoted above. The stratigraphic range comprises Lower to Middle Triassic with the presence of acid volcanoclastics.

Hronicum

Benkovsky potok Formation (Triassic), MaluΩina Formation (Permian). The uppermost unit of the Central Western Carpathians delimited in the map is the Hronicum. In smaller areal extent it is delimited in the area of the Vienna Basin beyond the northern rim of the map. Here on the basis of boreholes, but mainly on the basis of relations to surficial occurrences in the Malé Karpaty Mountains, we suppose in this section the Hronicum to be represented by Triassic and subordinately also by Upper Palaeozoic.

East of the Malé Karpaty Mountains there are Upper Palaeozoic (Permian) conglomerates, sandstones, shales, basalt, andesite and related volcanoclastics (MaluΩiná and NiΩná Boca Formations *sensu* Vozárová & Vozár 1981, 1988). Lower Triassic quartzites, shales and carbonates (Benkovsky Potok Formation, Biely *et al.* 1996) or Middle to Upper Triassic carbonates also were encountered in several boreholes drilled in the past (Biela 1979), also in the framework of investigation of the substratum of neovolcanites or hydrogeological investigations. On the basis of profiles of these boreholes and the course of general structures of the delimited Hronicum Unit we correlate it with surficial occurrences in the Tríbeè Mts and Hornonitrianska (Upper Nitra) depression area (Vozárová & Vozár 1974).

Fatricum

Vysoká and Krína nappes. The Fatricum is represented by the Vysoká Nappe in the Vienna Basin, and by the KríΩna Nappe East of the Malé Karpaty Mountains. In the Vienna Basin it constitutes a tectonic slice between the Tatric Devin and Borinka sequences below and the Upper Austroalpine Greywacke Zone above. There it is a good possibility of correlation of surficial occurrences of the Vysoká Nappe in the Malé Karpaty Mountains with borehole profiles in the pre-Tertiary substratum (Fusán *et al.* 1987). The prevailingly Triassic carbonates not divided more in detail in the map are present there.

East of the Malé Karpaty Mountains the Mesozoic of the KríΩna Nappe occurring just beyond the northern edge of the map is interpreted in connection with surficial occurrences of this unit in the Tríbeè Mts (Biely 1975) or in the PovaΩsk″ Inovec Mts. The KríΩna Nappe is well described also from boreholes in the Central Slovak neovolcanites, in the basement of the Hronicum Nappe (Polák 1978). So it may be concluded that a considerable surface delimited as the Upper Palaeozoic of the Hronicum can also overlap, at least partly, the Mesozoic (prevailingly the Triassic, less the Jurassic) of the KríΩna Nappe.

Southern Veporicum

Type of Federata–Tuhar development, Revúca Group, Ipoly Complex and other metamorphites, granitoids. The Southern Veporicum in the north-eastern part of the map is represented by crystalline rocks, mostly Lower Palaeozoic metamorphites, which we correlate with litho-stratigraphic complexes distinguished by Bezák (1982) in the Kohút Zone. The crystalline rocks are overlain by the Upper Palaeozoic of the Revúca Group (*sensu* Vozárová & Vozár 1982), Stephanian shales, sandstones, intermediate volcanites (Slatvin Formation) and Permian conglomerates, sandstones, acidic volcanoclastics (Rimava Formation). The Upper Palaeozoic Revúca Group is overlain by partly preserved Mesozoic; the Triassic or Jurassic (?) is assumed to belong to the Tuhár development, identical in position with the Federata Group (Rozlozsnik 1935, Biely 1956, Vozár in Bajaník *et al.* 1983, 1984).

The Southern Veporicum is affected by contact-metamorphic influence of Alpine granites (Vozárová & Kriπtín 1985, Vozárová 1990). These granites intruded into the structural zone of the Southern Veporicum, but also at the contact of the Veporicum and Gemericum and brought forth contact alteration of the Southern Veporic envelope as well as parts of the overthrusted Ochtiná Formation (Gemericum). From profiles of two boreholes (drilled by Nafta Gbely) GaΩa & Tanistrák described (in Biela 1979) such mineral assemblages which at present we may correlate with outcrops in the area of Krokava to Rochovce (Vozárová & Kriπtín 1985).

Along the Diósjenõ Line and under the volcanic mass of the Börzsöny Mountains and some Oligocene and Miocene sediments the Upper Triassic of the Transdanubian Range is in tectonic contact with the formations of greenschist facies belonging to the Ipoly Complex. The width of the tectonic zone was estimated by Balla & Korpás (1980) as broad as 1 km, surprisingly with a NW dip. Ophiolites in the zone, according to Schönviszky's calculations are supposed to be found towards the NE of the Naszály transversal fault. Along the Ipoly/Ipel' River and in the Hont area the basement rises up to the zero contour line while in the SW part of the region it sinks below –1500 m. The fault of NW–SE strike, cutting the Diósjenõ Line has an important role in this morphological differentiation. To draw the morphology of the basement seems to be an insoluble task since, according to the testimony of the borehole Perõcsény Pe–36, a subvolcanic body or bodies had intruded into the volcanic build-up in a way that they elevated a significant part of the crystalline basement on a huge area while in the break-through area large boulders were ripped off and transported to a higher level. This is why a situation could come into being that while in the broader surroundings the uplifted basement is in a depth of –800 m (Pe–8: –867 m), around the borehole

Pe–36 on an area with an unknown extent the borehole did not leave the andesite up to 1200 m whilst it had penetrated, 22.6 m and 63.8 m thick micaschist in –228 m and in –367 m respectively and an other 31.7 m thick crystalline-schist in –519 m. According to LELKESNÉ-FELVÁRI (1998) the Ipoly Complex consists of the alternation of brownish-grey and greenish-grey paragneiss and micaschist into quartzite and greenschist and rarely graphitic schist intercalate. The formation has been exposed in the following drill-holes: Diósjenõ Diós–1, –2, Hont H–1, –2, Perõcsény P–8, –36, Drégelypalánk Dp–2 and Nagybörzsöny Nb–7/a. As opposed to the prevailing micaschists and quartzites mentioned above, in the nearby drill-hole Balassagyarmat Bgy–5 muscovitic quartzite schist was discovered that suggests an eastwards change in the geological setting of the basement.

Northern Veporicum

Vel'ky Bok Group and Palaeozoic formations. The Northern Veporicum is interpreted on the basis of correlation with the northern Tríbeè Mts (group of Rázdiel). From sequences ranged to the Northern Veporicum we suppose the presence of Lower Palaeozoic metamorphites and granitoids, with an envelope of Permian terrigenous sediments and volcanites correlated with the Sk″cov Formation (VOZÁROVÁ & VOZÁR 1988) or with the Brusno and Predajná Formations (*sensu* VOZÁROVÁ 1979) and/or Triassic metasandstones, shales, carbonates sequences of Vel'ky Bok Group (*sensu* BIELY *et al.* 1992) in the L'ubietová Zone (Veporské vrchy Hills).

Central Alpine Unit, Tatricum

Tríbeè Group. The Tatricum structural megaunit is subdivided here into the of Tríbeè Group, the PovaΩsk″ Inovec Group and the group of the Malé Karpaty Mountains. It is for the first time that the Tatricum *s.l.* is divided into several structural subunits. In the past in literature views of the Malé Karpaty Mts as a Tatricum Unit with external position were presented or in the last time the problem of position of a part or of the whole Tríbeè Mts as a unit belonging to the Northern Veporicum has been discussed. At present it is the problem of searching for proofs for such a dissection of the Tatricum *s.l.* in the western and south-western part of Slovakia.

The Tríbeè Group is represented by Lower Palaeozoic metamorphites, crystalline schists, but granitoids are predominating. Petrologic studies of the granitoids of the Vel'k″ Tríbeè, mainly focusing on zircons indicated the identity of those granites with the granites of the Northern Veporicum (BROSKA & PETRÍK 1993). The envelope sequence is represented by the Lower and Middle to Upper Triassic (higher members are known neither from surficial occurrences nor from boreholes in the southern Tríbeè Mts area, group of Zobor). At surface, overlying them, the KríΩna Nappe was delimited, probably also preserved in the adjacent pre-Tertiary basement (BIELY 1977, FUSÁN *et al.* 1987).

PovaΩsk″ Inovec Group. This group is interpreted only on the basis of boreholes, also in correlation with surficial occurrences outside the map area. This group of the Tatricum is distinctly separated from other units by transform faults of NE–SW to N–S strike. Many boreholes (T–1, S–1, A–1) justify to delimit the Lower Palaeozoic crystalline rocks, mainly granitoids but also metamorphites (correlated with the occurrences near Hlohovec and Bojná). The envelope is made up by the ?Permian, but certainly by Triassic and Jurassic carbonates. The nappe units — KríΩna Nappe can be interpreted only on the basis of the structure of the PovaΩsk″ Inovec, southern part (FUSÁN *et al.* 1987).

Bratislava Massif, Modra Massif, Grobgneis Complex, Sopron Complex and Fertõrákos Complex; Lower Palaeozoic. The crystalline rocks of the Malé Karpaty Mountains consist of two granitoid massifs (Bratislava and Modra massifs) the tectonic contact of which is supposed on the basis of structural and geophysical data (MAHEL' 1986). These units belong to the group of the Malé Karpaty Mountains which represents the essential part of the outer Tatricum Zone and the predominating unit of the western part of the DANREG region.

Corresponding units in the Austrian part are the Grobgneis Complex with granitic ortho-gneisses, paragneisses, micaschists and amphibolites exposed in the Leitha Mts and the Hundsheimer Mt.

In the Hungarian part the Sopron Complex is correlated with the Grobgneis Complex and the Fertõrákos Complex with the Wechsel Complex. These units are exposed in the Sopron area and are known from several boreholes. The Sopron Complex (the Sopron Crystalline Schist sequence, *sensu* FÜLÖP 1990) is mainly made up by micaschist of sedimentary and gneiss of intrusive origin. According to FÜLÖP (1990) the original material of the micaschists might have been a sediment of Early Palaeozoic or perhaps Precambrian age. The Fertõrákos Complex of an Early Palaeozoic or even Precambrian sedimentary origin consists of feldspathic micaschists, phyllonitic micaschists, occasionally of graphitic micaschists, crystalline limestone and dolomite and of muscovite-microcline-albite gneiss. (More details are to be found in the explanatory notes of the surface geological map.)

The extension of these units below the Tertiary sediments is known from the wells of hydrocarbon prospection from which cores have been taken only at one or two hundred metre intervals. As a consequence of this operation none of the wells has penetrated nappe structures. The first evidence of the nappe structure was given by seismic measurements (POGÁCSÁS 1985). The greenschist facies metamorphites were first identified exclusively with the formations of the Sopron Complex (Grobgneiss) (BALÁZS 1975, VENDEL 1960). Later, formations rankable to the Fertõrákos Complex were also revealed (FÜLÖP 1990), however the data are still not sufficient enough to delineate the two units under subsurface conditions.

Micaschist composed of lenses of quartz with wavy extension, muscovite, biotite and occasionally garnet (almandin) in significant quantities were discovered in the wells Pinnye Pi–1 and Pi–2, Mosonszentjános Mos–1, Mihályi M–4, Mosonszolnok Msz–2 and Rajka Raj–1. Among its accessorial minerals mainly Ti-minerals, tourmaline and epidote are worth mentioning (FÜLÖP 1990). On the basis of their mineral composition he identified these rocks with the Sopron Complex. The chloritized and calcitized paragneiss with hornblendes, plagioclase, muscovite and a few biotite is considered by FÜLÖP (1990) to be identical with that of the Fertõrákos Complex. The muscovite paragneiss from the same well and the wells Mos–1, Mos–2 and Msz–2 were found by him lithostratigraphically unrankable. According to LELKESNÉ-FELVÁRI (1989) these formations are of Ordovician–Silurian age. She explains the uncertainty of age determination with the overprint of Eo-Alpine and Alpine thermal metamorphoses.

Red sandstone and siltstone were described in the primary report of the well Msz–1 just above the rocks of green-schist facies. The same qualification can be found in the Mosonmagyaróvár atlas [SCHAREK (ed.) 1989]. These rocks were mentioned as tuffitic sandstone and identified with the "verrucano" series in a study (MATTICK *et al.* 1996 manuscript) that was a by-product of the hydrocarbon prognostic work of the Kisalföld. It is strange that FÜLÖP in his monograph on the Palaeozoic (1990) did not even mention this formation. It is also strange that the well itself is not referred to either. If we think of the Permian–Mesozoic sequence found on the surface and explored by boreholes on the north-western (Austrian) side of the Central Alpine Crystalline Zone underwent a significant metamorphosis (*e.g.* "Semmeringquartzite") while a huge mass of the Northern Calcareous Alps was thrusted over these rocks it is hard to imagine that they remained unmetamorphosed on the SE side of the same zone. For this reason I believe that the mentioned formation belongs to the Miocene succession forming its basal (terrestrial) unit.

The Sopron Hills are of imbricated structure (FÜLÖP 1990). According to the seismic data two imbrications of eastward oriented movement can be proved in the basement. The strikes of the thrust plains are close to parallel or coincide with the strikes of the main faults. In different maps the contact between the Central Alpine Crystalline Zone and the "Rába Metamorphite Group" adjacent in the E is indicated by a single tectonic line. According to FÜLÖP (1990) it is a young left lateral fault while on the present map it coincides with a major fault. The real contact between the two units probably coincides with an imbrication or eventually with a thrust plain of a nappe but its delineation can not be made at the given density of wells, therefore the problem is solved only formally.

Pezinok–Pernek Zone. The second part of metamorphites of the Malé Karpaty Mountains, the Tatricum is designated as the **Harmónia Formation** of the Pezinok–Pernek Zone. It is made up by Lower Palaeozoic metamorphosed sediments and basic volcanites including vein equivalents, sporadically also occur lydites and bituminous shales. These metamorphites were compared by PAHR (1983) with the Wechselserie and by LESKO & VARGA (1980) with analogues of the Veporicum.

The crystalline rocks above are delimited in the Harmónia Formation and a Devonian age is attributed to them on the basis of acritarchs, palynomorphs, chitinozoans and crinoids (ÈORNÁ 1968, PLANDEROVÁ 1984). The Harmónia Group is affected by contact metamorphism from the side of the granitoid Modra Massif (CAMBEL 1976).

Borinka, Devín and Semmering sequences (phyllites, quartzites, marbles; Permian to Jurassic). The envelope series of the Tatricum in the Malé Karpaty Mountains, are represented by the Devín, Borinka, Oreπany, Kadlubek sequences (MAHEL' *et al.* 1984). In the map only the first two occur. The Devín sequence in the southern part of the mountains ranges from the clastic Permian to Lower Triassic through Middle Triassic carbonates to the Jurassic (up to ?Lower Dogger). The Borinka sequence in the basal part is tectonically amputated and the stratigraphic range from the Middle Triassic to the Upper Jurassic is preserved (MAHEL' 1986).

The envelope series of the Tatricum occurring at the western margin of the Malé Karpaty Mountains continue widespread into the pre-Tertiary basement of the Vienna Basin where it is involved with the Vysoká Nappe in complicated imbrications.

In Austria the south-western continuation of the Tatricum is the low grade metamorphic Semmering sequence of Central Alpine facies with Permian–Mesozoic phyllites, meta-conglomerates, quartzites and marbles forming the primary sedimentary cover of the Grobgneiss Complex.

Pelso Unit

The DANREG programme deals with the smaller part of the Transdanubian Range of the Pelso Unit. The distribution of the Mesozoic and the older formations in the Transdanubian Range outlines a syncline the axis of which is broken twice while the subsiding western wing keeps its dominant NE–SW strike. In the axis of the syncline the Upper Triassic to Middle Cretaceous formations are situated while on the wings there are rocks down to the Palaeozoic. The first break in the axis of the syncline is at the southern part of the Tatabánya Basin where the NE–SW orientation is taken over by N–S orientation. Even more striking change can be observed in the axis of the syncline and in the strike of the succession at the NW corner of the Gerecse. Towards E from here the strike changes to E–W orientation.

On the whole the characteristic tectonic lines in the map form several triangles with a widening base of an E–W orientation along the southern border of the map. These lines are either dilatational or transpressional ones.

A pre-Eocene (Subhercinian?) overthrust line with a southern vergency at Vértessomló is the base of the triangles. Along this line or parallel to it some less significant strike-slip faults appear usually diminishing the slickensides belonging to the earlier movements.

The Dorog Basin represents a special case where the characteristic structural direction is E–W.

The age of the structural elements delineated on the basement map, without special studies, can be estimated only with uncertainty. The structural lines along which only changes of formations can only be noted without altitude differences were developed during the erosional period before the deposition of Tertiary cover. Among them the best examples are the troughs filled with Cretaceous and Jurassic formations. Structures after the Middle Cretaceous and before the Middle Eocene are known at Kisbér, in the Oroszlány and Vértessomló basins, at Agostyán and in several places in the Gerecse Mountains and the Dorog Basin. If the surface of the basement on both sides of the fault is situated in different altitudes it is a clear evidence that the structure is younger than the formation directly covering the basement. The inner basins of the Gerecse (Vértestolna, Héreg–Tarján, Csorda-kút–Nagyegyháza, Mány and Zsámbék basins and the stretches of the Dorog Basin) are good examples for those cases where the faults are post-Eocene or even post-Oligocene. It is a common case that the pre-Eocene structures are rejuvenated after the Eocene or even the Oligocene period, just like in the Tatabánya Basin. The explanation and interpretation of this situation is a due of the authors of the tectonic map.

In the relevant parts of the Transdanubian Range a great proportion of the pre-Mesozoic and Mesozoic (from the Middle Triassic to the Middle Cretaceous) formations can be found on the surface, too. Their overview has been given in the explanatory notes of the surface geological map, therefore in the following the attention will be focused on the overview of the formations ranging from the Palaeozoic to the Middle Triassic and on the Middle Cretaceous formations.

Lower Palaeozoic

Palaeozoic formations are exposed on both wings of the syncline in the Transdanubian Range, but within the map area no well reached rocks belonging to them. However, on the northern wing of the syncline, near the southern margin of the sheet, several wells intersected anchizonal metamorphites in considerable thickness that are in many respect similar to the Rába Metamorphite Group. The first detailed description and interpretation of the formation dis-covered in the Tét Anticline was given by Fülöp (1990) under the name **Tét slate formation**. The peculiarity of the anticline is that on the NW side of the syncline, opposed to the southern wing, Palaeozoic formations occur again, in front of the Rába Zone Triassic sediments. The formation called Vaszar slate by Balla (1994) and Vaszar schist formation by Mattick *et al.* (1996) was encountered by 11 (or 12) wells. The well Gyõrszemere Gysz–2 is considered as the 12th one that was only mentioned by Teleki *et al.* (1989). The connection between the rocks discovered here and the Middle and Upper Triassic formations is not mentioned. Petrographically the formation is consists mainly of claystone schist and siltstone schist to which sandstone-schist and meta-sandstone are joined in varied frequency. Its mineral composition is made up of: quartz, low temperature albite, sericite, chlorite and pyrite. The rock is usually grey or greyish-green but in spite the lithological similarities in the wells Csót Cst–1, Alsószalmavár Asz–1 and Bakonyszentlászló Bszl–6 the brownish-red colour is dominant. On the basis of the above mentioned, the breccia intercalations of sliding origin and the silica cement in the beds, Fülöp (1990) qualified this formation as a shelf slope sediment. Its age is known only from radiometric dating: 311 and 329±13 Ma that correspond to the time interval between the Lovas Slate Formation and Révfülöp slate formation of the Balaton Phyllite Group, that is to the Silurian. In the core of the anticline the Tét slate is also present. The anticline flattens out towards the north-east and along a NW–SE oriented fault at Nyalka and Táp probably disappears. According to the seismic data and the well Tét–4 (Mattick *et al.* 1996) an intrusion of mafic composition is proven in the core of the anticline. This intrusion is called as “Sótony diabase”. As it is evidenced by the seismic profiles the Tét formation is thinning out to the north-west as it is thrusted over the above mentioned intrusion. In the light of the palaeogeographic conditions (the structural units on the two sides of the Rába Zone are different in origin) the name “Sótony diabase” seams inappropriate.

A particular problem is the deeper substratum, *i.e.* sequences still established underlying the Mesozoic or Triassic to uppermost Permian of the so called Kolarovo high block. A solution for the interpretation of this deeper substratum, which is not delimited in the compiled map of the pre-Tertiary basement (remark of the author: the map shows the close pre-Tertiary basement only) has been brought by data from borehole ZH–1 (Zelen″ Háj). From horizons below the Permian–Triassic sequence (cfr. borehole M–2, Modrany, GaΩa & Beinhauerová 1974) horizons of dark-grey lydites, shales, dark-grey and greyish-brown nodular limestones (1666.0–1756.0 m) were established. From them Biely & Kullmanová (1979), Kullmanová & Biely (1981) described tentaculites of Middle Devonian age and correlated the encountered sequence with the Devonian of the southern Greywacke Zone and Palaeozoic of the Mihályi High in Hungary. On the basis of lithology and fossil content this tentaculites bearing limestone can also be correlated with the Kékkút Limestone Formation within the Pelso Unit (Fülöp 1990). Similar Lower Devonian formations are known in the Karnic Alps (Findenigkalk — Bandel 1972; Schönlaub & Flajs 1975), in the Karavanke Mts (Ebner 1975) and in the Greywacke Zone (Schönlaub 1979).

Upper Permian

The sedimentary cycle beginning with the Upper-Permian formations is preceded by a significant erosional gap. The boreholes explored successions of river channel and flood plain facies well identifiable with those known in the Balaton Highland (MAJOROS, 1980, 1983). Red and subordinately grey conglomerates, sandstones and mudstones are the significant rock types of the **Balatonfelvidék Sandstone Formation** of cyclic development and fining upward grain size. The basal conglomerate beds distinguished on member rank, have not been developed everywhere on the western wing of the syncline. The most important wells and boreholes situated close to the southern border of the map sheet are as follows: Csót Cst–1, Alsószalmavár Asz–1, Bakonyszûcs Bsz–I, Tét–2. In the latter one the Tabajd Anhydrite Formation and the Dinnyés Dolomite Formation of sabkha and lagoonal facies have been encountered (MATTICK *et al.* 1996). This is an evidence for the invasion of the Late Permian sea farther to the west than it was experienced in the southern part of the syncline in the Transdanubian Range. Formations of undoubtedly Permian age have not been revealed by drilling within the map area. The red-brown clayey sandstone that was reached at the base of the well Visegrád V–3 underneath the Upper Triassic carbonates may be classified to here. In addition to the Balatonfelvidék Sandstone the Tabajd Anhydrite and the Dinnyés Dolomite have also been found in the boreholes Tabajd T–5 and the Alcsútdoboz Ad–2 near the southern margin of the map, on the south-eastern wing of the syncline. The **Tabajd Anhydrite Formation** of restricted lagoon facies consists of an alternation of red and grey siltstone, dolomite, anhydrite and gypsum. The **Dinnyés Dolomite**, laterally interfingering with the Tabajd Formation of 300 m maximal thickness contains a few siltstone and sandstone beds, too. From among its rich and varied fossil content the following groups are worth mentioning: benthic foraminifers, sporomorphs, green and red algae, ostracods and in some places gastropods.

The works of BARABÁS-STUHL (1975), HAAS *et al.* (1986, 1987) and GÓCZÁN & ORAVECZ-SCHEFFER (1987) documented progress in the stratigraphic subdivision of the Permian formations. A more typical succession of the Tabajd and Dinnyés Formations is revealed in the boreholes Dinnyés Di–1, –3 and Gárdony G–1, –1a in the area of Lake Velence. This data indicate the direction of a more open marine environment that existed already in the Early and Middle Permian.

Lower Triassic

Although the Permian and the Triassic formations are considered as members of a long-duration sedimentary cycle (HAAS *et al.* 1995), in the western part of the Transdanubian Range there is a gap between the two sequences gradually vanishing eastwards. On the basis of the lithofacies at the base of the Triassic MAJOROS (1980, 1983) distinguished four types of contact. Out of them only one has been proved by FÜLÖP (1990) in the area of the map. It begins with a basal conglomerate after a gap in the Tét area. In case of continuous transition is doubtless, where the boundary can be drawn within the slightly sandy, ooidic, biosparitic calcarenite of the **Alcsútdoboz Limestone** located above the dolomite on the southern wing of the syncline.

The **Arács Marl Formation** is only present on the northern wing of the syncline in the form of grey clay-marl and siltstone (Gyõrszemere Gysz–2), siltstone, claystone and sandstone (Alsószalmavár Asz–1) with a thickness of 150 m in the former case and 230 m in the latter one. Gypsum or anhydrite lenses are common (RAINCSÁK in BENCE *et al.* 1990). The **Hidegkút Formation** is developed continuously from the Arács Formation. It is easy to correlate it with the beds discovered in the borehole Bakonyszûcs Bsz–3 in a thickness of 43 m without cutting it through compeletely. On the basis of the description this formation can not be distinguished in the well Asz–1. The formation consists of red and reddish-brown, often platy quartz-sandstone beds which have ripple marks at its type locality in the Balaton Highland.

Despite its lower tectonic contact the virtual thickness of the **Csopak Marl Formation** is 127 m in the borehole Bsz–3. Its presence in the well Asz–1 can only be supposed from the original report of the well. Based on the previous borehole the formation consists of, greenish-grey clay-stones, clay-marls and marls with dolomite and limestone lenses and limestones with dolomite and dolomarl intercalations. Near its base it also contains gypsum and anhydrite nodules and veins. Based on the seismic profiles the total thickness of the Lower Triassic sequence, known as the Werfen Group, can reach 600 m, while the Csopak Marl often thinned out because of tectonic reasons (MATTICK *et al.* 1996).

As we have seen, the Werfen Group is lithologically closely related to the Permian formations in the studied parts of the Transdanubian Range. However, as far as the environment of sedimenation is concerned, there is a basic difference between the two, since the Triassic formations are fully marine. The once significant morphological difference between the sedimentary basin and the source area gradually disappeared about the end of the Early Triassic, therefore the clastic sediments were slowly substituted by carbonates. From that time on with episodic gaps and varied intensity carbonate sedimentation was taking place until the end of the Jurassic in the Gerecse Mountains, elsewhere even till the end of the Early Cretaceous. In the meantime the arid or at least semiarid climate persisted.

Middle Triassic

As opposed to the Lower Triassic, the Middle Triassic formations are also known from outcrops in the eastern part of the sheet. Despite of much uncertainty it is a well-known fact that starting at least from the Ladinian age two types of successions can be distinguished in the Transdanubian Range. The eastern area is dominated by platform carbonates (Diplopora dolomite) while the western one by sequences of basin facies character dissected by smaller reefs. A further difference is that while tuff beds are characteristic for the basin area such beds are almost completely missing in the eastern part.

The **Aszófõ Dolomite** is the oldest Middle Triassic formation which has been cut by the borehole Bsz–3 in the North Bakony Mountains in a thickness of slightly more than 100 m. There the formation is brownish-grey, porous, locally cellular, platy or well bedded with clay and marl on the bedding planes or as thin intercalations. Muscovite crystals are common on the bedding planes and there are gypsum infillings or calcite pseudomorphoses after gypsum in the little holes (HORVÁTH in CSÁSZÁR *et al.* 1984). It is revealed only in the well Gysz–2 on the map area where the formation is in tectonic contact with the Megyehegy Dolomite Formation.

As it is evidenced by the borehole Bsz–3 the **Iszkahegy Limestone Formation** developed gradually from the Aszófõ Dolomite (HORVÁTH in CSÁSZÁR *et al.*,1984). The thickness of the Iszkahegy, Aszófõ Formation that consists of the alternation of limestone and dolomite beds is 56 m. The typical Iszkahegy Limestone is 44 m there. It consists of grey, well-bedded and platy, slightly clayey, sometimes slightly nodular limestone with clay strings. This limestone has been deposited in an at least partially restricted basin. The dolomite breccia with limestone cement and sedimentary folds suggest a slope facies sedimentation. The rare dolomite intercalations are porous and featured by calcite dots. Similarly to the underlying, transitional beds (Megyehegy, Iszkahegy Formation) are deposited also in the overlying beds of the formation in the same borehole with a thickness of 63 m. Although in this transitional interval the main rock type is the dolomite, the appearance and stratification of these beds are rather similar to the Iszkahegy Formation including their slump structures. According to RAINCSÁK (in BENCE *et al.* 1990) the formation is also present in borehole Asz–1.

The **Megyehegy Dolomite Formation** has been encountered on the north-western wing of the Transdanubian Range syncline in the borehole Bsz–3 off the map area and also in the Gysz–2 and –3 within the sheet area. The lower contact of the formation is tectonic in the last two wells (MATTICK *et al.* 1996). It is in touch with the Aszófõ Dolomite in the well Gysz–2 and with the Tét slate in the Gysz–3. The light grey-brown thick-bedded dolomite contains little holes arranged in strings. The uppermost beds are rich in large oncoids and the lower 30 m in authigenic breccias. The Middle Triassic formations reviewed above are extremely poor in fossils: except for the Iszkahegy Limestone they contain almost no macrofauna.

There is a gradual transition between the Megyehegy Dolomite and the **Felsõörs Limestone Formation** in the borehole Bsz–3 (CSÁSZÁR *et al.* 1984). The lower transitional interval of the 36 metre-thick Felsõörs Formation is composed of marl and dolomarl that is followed by nodular limestones with clay strings nodular cherts and tuff intercalations. In its upper part the limestone is aphaneritic, well bedded with flaser structures and a few chert nodules. This pelagic limestone is characterised by nektonic and planktonic fossils such as ammonites, radiolarians and also conodonts (VÖRÖS 1987, BUDAI 1993, HAAS 1994). As rare exceptions crinoidal limestones can also be observed. The presence of the formation has been proved in the well Bsz–I as well (MATTICK *et al.* 1996).

About the Tagyon Limestone of platform facies (a heteropic facies of the Felsõörs Limestone) there is information only from the Balaton Highland. The **Buchenstein Formation** that was intersected 13 m long in the borehole Bsz–3, suggests the paroxysm of the volcanic activity and at the same time a renewed rifting of the Tethys Ocean. The lower part of the formation is characterised by the alternation of tuffite and limestone beds of varied thickness. In the upper part the alternation of silicified, hard tuffite (siliceous shale) and soft tuffite beds with subordinate limestone plates is characteristic. Approximately one third of the tuffite is a crystal tuff origin while two thirds are volcanic ash (powder tuff) with biotite crystals. The fauna of the limestone plates corresponds to that of the Felsõörs Limestone. The upper boundary of the formation can not be drawn with certainty since the characteristic tuffite beds occur also in the overlying limestones. East of the Bakony Mts only one occurrence is known at Mány village in the borehole My–1 where it occurs in unusual setting, namely overlying of the Budaörs Dolomite as a 2.1 m thick tuff bed of yellowish-green colour.

The occurrence of the **Budaörs Dolomite Formation** of platform facies with green algae (mainly *Diplopora annulata*) is only proved from the eastern part of the Transdanubian Range, on the south-eastern wing of the syncline. Its typical occurrences apart from the ones in the Budaörs area in the south are in the Meszes–Nagyszénás-Zsiros Hills area, north of Nagykovácsi, but there are smaller outcrops in the neighbourhood of Mány and Zsámbék as well. The geological knowledge of the area is heterogeneous as so far research has been done so far only to solve various scientific problems in the Buda Hills. Consequently, the surface extent of the Budaörs Dolomite is different in the various earlier maps. The same is true for the extension of the formation in the covered areas. The most reliable datum is the borehole Budajenõ Bj–2 in which the virtual thickness of the formation is 434 m without its lower and upper stratigraphic contacts. Further boreholes where it has been reached are as follows: Mány M–7, –8, My–1 (under the Hauptdolomit onto which the Veszprém Marl was overthrusted) and Zsámbék Zs–14 (under Hauptdolomit and Veszprém Marl) *etc.* The formation comparable with the Wetterstein Dolomite consists of white, greyish-white, thick dolomite banks sometimes with red patches and crystalline texture. The formation with its estimated thickness of 1300 m includes algal laminitic intercalations in the Csiki Hills (WEIN 1977). According to him the underlying formation is unknown and the dolomite is overlain by a 500–600 metre-thick white, pink or yellowish dolomite with loose structure that, —based on its rare and uncertain green algae content— was considered by WEIN with uncertainty to be a member of the Budaörs Formation. Based on the boreholes Solymár So–42, –62, –89 (WEIN, 1977) south-east of Solymár this latter formation is provisionally named Solymár formation while in the Nagyszénás area it is united with the Budaörs Dolomite.

Upper Triassic

The **Füred Limestone Formation** is a heteropic facies of the uppermost, non typical succession of the Budaörs Dolomite that extends into the Carnian. This formation is mentioned only from the borehole Bakonyszücs Bsz–3 located in the southern border area of the map sheet. There this 15 m succession is referred to as Nemesvámos limestone (CSÁSZÁR *et al.* 1984). The limestone of basin facies is light-grey, with nodule-like structures, clay or tuffite laminae, and small chert nodules. Its fossil assemblage, apart from the crinoids, corresponds to that of the Felsõörs and Buchenstein Formations.

Although the Upper Triassic consists basically of platform carbonates in a thickness of 2000 m or even more, a significant part of the Carnian stage in the area is made up by the **Veszprém Marl Formation**. In the North Bakony Mts or in the Zala Basin it can be as thick as 1000 metres or more while it is a few hundreds of metres elsewhere. The formation of inner platform-basin facies suggesting a more humid climate than before is composed of fine-grained clastics: marl, clay-marl, siltstone-marl, in which fine-grained sandstone lenses and, mainly in the upper part calcareous marls and clayey limestones are common. The formation has been penetrated in the greatest thickness (1153 m) in the borehole Bakonyszücs Bsz–1 without its stratigraphic contacts. It has also been reached by the wells Bsz–2, Bsz–I and the Gönyû–1. Its lack in the well Gyõrszemere Gysz–2 may be due to tectonic reasons (MATTICK *et al.* 1996). Deeper and shallower basins and swells are juxtaposed, in part perpendicularly in part parallel to the axis of the syncline [HAAS (ed.) 1993, HAAS 1995]. The pelites are replaced by carbonates. Its thickness in the North Bakony Mts is a few tens of metres only. In the Zsámbék area (borehole Zs–14) it gets thicker again and the pelite content slightly increases. The formation is subdivided here into a lower and an upper part by the Mátyáshegy Formation [CSILLAG & HAAS in HAAS (ed.) 1993). In the area it has been intersected by some more drillholes: Mány My–1, Zsámbék Zs–6 and Tök–1 (about 200 m, neither with overlying nor underlying beds), Tök–4 and Zsámbék Zs–23, –42. The occurrence of the Veszprém Marl in two stripes in the South Gerecse affirms the probability of the eastwards continuation of the Vértessomló overthrust and also its connection with the Nagykovácsi overthrust despite of the fact that these two lines are not continuations of each other today. Their different positions may be explained with the considerable faults of the Zsámbék Basin. This model does not explain the westward continuation of the northern repetition of the Budaörs Dolomite in the Buda Hills.

The **Mátyáshegy Formation** is in part a heteropic facies of the Veszprém Marl. According to HAAS (1994) this formation comprises two lithologic units. Its lower part is dominated by limestones, its upper part by dolomites. Chert nodules and lenses are characteristic for both units. In this basinal carbonate facies there are intervals without chert as well. Therefore the stratigraphic classification of various kinds of dolomites appearing in different levels is not promoted unambiguously by the definition. It is an indication of needs for further mapping. In KORPÁS 's manuscript map the dolomite occurrences without cherts found on the Hármashatár Hill are ranged also here. Both in the present map and the surface geological map this formation is indicated under a preliminary, informal name (Hármashatárhegy dolomite — see also the explanatory notes of the surface geological map). Important subsurface data have been gained from the drillholes Városmajor Vm–1 and Vérhalom–1. In the latter one, according to KORPÁS (personal communication) cherty limestone with marl, dolomarl and dolomite intercalations have been discovered in a thickness of 200 m without reaching its underlying beds.

The Veszprém Marl comprises two rock bodies in the borehole Zsámbék Zs–14. The lower one is 240 m thick and may correspond to the Mátyáshegy Limestone while the upper one, the Sashegy Dolomite Member, is 50 m thick.

Based on the study of the occurrence on the Mátyás Hill the deposition of the formation comprises the time interval between the Carnian and the Rhaetian (KOZUR & MOCK 1991, DOSZTÁLY in HAAS *et al.* 1997). Taking into consideration the Csõvár analogies the extension of the formation up to the Jurassic can not be neglected. Consequently, it seems senseless to look for a connection between the e Mátyáshegy Formation and the other formations in the Buda Hills, especially if we consider that the Veszprém Marl appears again overlying the Mátyáshegy Formation in the Zsámbék area with an identical lithologic composition and 200 m total thickness (HAAS 1993). The succession is followed by a thick Hauptdolomit and the even thicker Dachstein Limestone.

The detailed description and evaluation of the **Hármashatárhegy dolomite** is given in the explanatory notes of the surface geological map. If it is accepted that the mass of Hármashatárhegy dolomite consists of basin facies formations and that towards the east and west it is flanked by platform facies, from both directions formations of slope facies may be attached to it. This is demonstrated in the map by extending the Hármashatárhegy dolomite also to the covered area eastwards.

One of the most extended formation of the area is the **Hauptdolomit Formation** that spreads over significant territories on both wings of the Transdanubian Range. This is the youngest Mesozoic formation of the basement directly under the Tertiary sediments between Pannonhalma and Komárom in an approximately 10 km-wide stripe on the north-western wing. It has been penetrated here by relatively few wells and boreholes: Gyõrszemere Gysz–2 (at its lower boundary a tectonic contact with the base of the Middle Triassic or with the top of the Lower Triassic), Pér–1, –2, Nagyigmánd Nig–3, Ács–1 and the "Kendergyár well" at Komárom. On the south-eastern wing between Tatabánya and Szentendre it forms a 5–15 km-wide arched zone. Due to the overthrust at Tatabánya, along the Vértessomló imbrication the zone surrounds a narrow Dachstein Limestone stripe while in the Mány and Zsámbék area and at Budapest a larger patch of the Budaörs Dolomite occurs. In the area it has been reached by a great number of boreholes. In the boreholes Epöl–I and Budakeszi–1 its thickness is considerable. According to [HAAS (ed.) 1993] the formation is built up of light-grey, grey, mainly thick-bedded dolomite beds. The sedimentation area is changing between peritidal zone and lagoon; as a result the formation is lofer-cyclic in structure. The thick 1500 to 2000 m sequence is hard to subdivide into units. Its underlying on the larger part of the area is the Veszprém Marl (western wing of the syncline and the Mány–Zsámbék area), and the Mátyáshegy Formation (Vértes Mountain and probably its northern continuation and the Buda Hills) respectively. The situation in the Buda Hills is ambiguous; if the Mátyáshegy Formation as a basin facies sediment fills the entire Upper Triassic while in the Jánoshegy horst-block the Ladinian and the Norian–Rhaetian are also represented by platform carbonates (and the presence of Carnian sediments is not proved yet), then the underlying of the Hauptdolomit can only be supposed.

The Hauptdolomit is overlain everywhere by the **Dachstein Limestone**. The transition between the two formations is known only in part. According to the improperly evaluated (or even insufficiently observed) data the character of the transition is rather varied. There are no boreholes known in the basement of the Kisalföld that would have penetrated the transitional beds named as Fenyõfõ Member. Its thickness in the North Bakony varies between 100–200 m and it usually consists of an alternation of well-bedded dolomite, limestone an their transitional rock types, where red shade is common. In the Buda Hills the transitional beds can be as thick as 30–100 m (WEIN 1977). There the succession consists of alternating brownish-grey dolomite and white limestone. Its virtual thickness in the borehole Adyliget–1 is 118 m (HAAS 1989). In the Gerecse Mountains is even less clear. This can be explained in part by the high grade of tectonism of the area. Underneath the Tertiary cover the width of the Fenyõfõ Member can be 5 km as a maximum where the limestone beds or packets seem to alternate with dolomite banks. In the Epöl area, however, marl intercalations are not rare either. Its thickness in the borehole Ep–5 is 206 m (HAAS 1989). The Halorella and Halobia beds are also significant there. To clear up and outline an unambiguous picture about the relation between the two formations from place to place is for the time being beyond the possibilities of the authors of the map.

The lower transitional interval of the Dachstein Limestone discussed previously in many respects resembles the **Feketehegy Formation** the occurrence of which, according to [HAAS (ed.) 1993], is restricted to the Pilis Mountains. In addition to its outcrops a part of the section in the borehole Pilismarót Pm–3 is ranged here too.

Kössen Formation has not been reported from the map area so far. The Feketehegy Formation may correspond to it, at least in facies.

The **Dachstein Limestone** is the most wide-spread formation on the surface of the pre-Tertiary basement. This is the youngest, generally extended formation of the Triassic built up of lofer cycles. The most characteristic fossils of the subtidal zone are the Megalodus, Triasina and the Oberhauserella. Often dolomitic algal mats have developed in the intertidal zone, while, paleosols in the supratidal one (HAAS 1982, 1989). The Fenyõfõ Member consisting of the transitional beds belongs here too. Oncoidal and gastropod-bearing limestones with coral colonies were developed in the Buda Hills indicating a lagoon of relatively agitated water nearby reefal environment. The black limestone breccia ("black pebble") horizons are a typical and common element of the formation.

On the north-western wing of the syncline the Dachstein Limestone has been encountered in a bit deeper position by a few boreholes. The Nagyigmánd Nig–1 and a water well at Tata are worth mentioning. The greatest thickness of the formation was documented in the latter (1200 m, without stratigraphic contacts). Along the axis of the syncline and south-east of it the Dachstein Limestone has been reported from several hundreds of drillholes at least with a few m in thickness. The most important ones are as follows: Epöl Ep–5, Adyliget–1, Pilisszántó Psz–1 and Budakalász Bk–I in which a few hundreds of metres have been drilled. According to ORAVECZ-SCHEFFER (1987) the formation is Late Carnian to Rhaetian in age. Normally it is overlain by Tertiary sediments but the Jurassic Pisznice Limestone Formation also occurs directly overlying it.

In the Dunazug/Visegrád and the Börzsöny Mountains and in the area east of the Danube the data are insufficient for dividing the Triassic sequences into formation rank units and especially for outlining their geographic extent. From these boreholes mainly limestones were mentioned (Vác B–58, Visegrád V–3) but there are a few where limestone and dolomite occur equally (Göd–3, Szentendre Sz–3), while elsewhere the data are contradictory. In one of the primary reports of the well Paskálmalom Pm–1 there is dolomite, in the other one limestone is mentioned. According to KOVÁCSNÉ-BODROGI (1981) there is only dolomite in a 118 m thick interval in the well Pilisszentlászló Pszl–2 while 50–94% of $CaCO_3$ was reported after the lab investigation. There is nothing known about the carbonate composition of the Triassic rocks in the well Leányfalu Lf–1. Based on the above mentioned facts and also by taking into consideration the general north-western dip of the Triassic in the Pilis Mts we believe that the Dachstein Limestone is the most widespread Mesozoic formation underneath the Tertiary. Due to tectonic reasons the Hauptdolomit may also have a great extent here. This idea is supported by the almost exclusive occurrence of the Dachstein Limestone on the surface and in boreholes in the Naszály environs. Some facts, however, made me cautious. In the SE part of the Naszály outcrop the maps indicate a transitional formation. On the nearby Csõvár horst block, out of the map sheet the **Csõvár Limestone Formation** crops out that is in part a heteropic facies of the Dachstein Limestone. It is deposited on the slope going towards the nearby oceanic basin. As it became clear from HAAS *et al.* (1997) paper, the nappes also have to be taken into account in the area. In the borehole Csõvár–1 below the 600 m thick Csõvár Limestone a completely different Triassic sequence is discovered that in addition to the Upper Cretaceous marl tectonically includes various other Cretaceous and Jurassic limestones (HAAS *et al.* 1997).

Jurassic (to lowermost Cretaceous)

The Jurassic formations are very restricted in extent in the area. They basically occur in the axis of the Transdanubian Range syncline or in the adjacent areas, almost exclusively in the *s.l.* ammonitico rosso facies with continuous sequences in the basins and discontinuous ones on the highs (CSÁSZÁR *et al.* 1998). The only exception is the Csõvár occurrence where, according to KOZUR (1993), the Lower Jurassic developed with gradual transition from the Triassic Csõvár Limestone with the same lithology.

The total thickness of the Jurassic sequence is dwarfed even by that of a single formation of the Triassic. With the opening of some new branches of the Tethys Ocean extensional movements took place in the area. Thereupon the widely extended carbonate platforms, characteristic for the Triassic in general but especially for the Norian–Rhaetian age, broke up into pieces and within a short time interval became divided into highs and basins. In peculiar way the equal but rather fast subsidence during the Triassic was replaced by an unequal one. If the interpretations concerning the water depth are accepted than the subsidence rate must have been decreased instead of increasing, since basically no sedimentation took place in the Jurassic as opposed to the accumulation of the Triassic. The total thickness of the Triassic sediments might have exceeded 3000 m during 37 million years (HARLAND *et al.* 1989), while during the 62 million year-long Jurassic period a maximum of 100 metre-thick sequence of sediments has accumulated in the Gerecse Mountains, albeit the water depth hardly exceeded 1000 m. The subsidence rate was 81 m/Ma in the Triassic while 1.6 m/Ma in the Jurassic.

An overview of the sedimentation on the highs and basins has been given in the explanatory notes of the surface geological map. Continuous sequences of basinal facies covered by Cretaceous, Eocene and in smaller parts by younger beds are reported from the Dorog Basin (D–166, T–393, –411, –464, M–72, N–34, –44 *etc.*) from the Pilis Mountains (E–69) from Tata, from the Tatabánya Basin (Ta–1472, –1485, –1492) from the Vértessomló Basin (O–1822, K–1) and from the Kisbér area (K–106). According to the data the Tatabánya Basin undoubtedly was in connection with the Vértessomló Basin forming a uniform basin but the northern part of the former one probably was the slope of the Gorba High situated between Szomód and Tardos. The slope is evidenced by the drillhole Ta–1462 in which the Upper Jurassic Pálihálás Limestone rests on the Lower Jurassic). Another high is outlined south of Vértessomló in the Oroszlány Basin (the O–1825 is already highly discontinuous).

Cretaceous

The Cretaceous formations restricted to the axis of the Transdanubian Range syncline develop gradually from the Jurassic in the above mentioned basin areas as the boundary is found within the Szentivánhegy Limestone. In the geological history of the area the changes that took place between the Berriasian and the Hauterivian are marked by siliciclastic formations. These succeeded the generally spread limestone formation westwards with some delay (CSÁSZÁR 1995). The presence of rock fragments of the oceanic crust in the sediments testifies to the partial closure of this branch of the Tethys Ocean (CSÁSZÁR & ÁRGYELÁN 1994; B. ÁRGYELÁN & CSÁSZÁR 1998). The description of the formations belonging to the Gerecse Group is found in the explanatory notes of the surface geological map.

The **Bersek Marl Formation** has outcrops in the East Gerecse. Its subsurface occurrences were recorded from the Dorog Basin and the Pilis Mountains. It is replaced by the **Lábatlan Sandstone Formation** that extends westwards from the Dorog Basin to Szomód and towards the south as far as the Tatabánya Basin. A heteropic facies of the Lábatlan Sandstone is the **Tata Limestone Formation,** the easternmost occurrences of which are in the Tatabánya Basin (Ta–1329, –1472) and in the Vértessomló Basin (Vs–6, Vst–8). Although the separated appearance of the Tata Formation of Aptian to Early Albian age (SZIVES 1999) is mainly the result of subsequent erosion, but a sequence with unequal thickness was deposited after and above the south-westward increasing gap in the basins dissected by uplifts. At present the formation appears as a separated patch with a thickness of 217 m in the well Kisbér K–106. The complicated geological history of the area is well reflected in the complicated distribution of a facies system the Tata Limestone is also included in. The siliciclastic sedimentation in the Gerecse Mountains and the lack of the Lower Cretaceous formations south-westwards from the Vértessomló Basin is a consequence of compressional tectonism in the Late Jurassic and Early Cretaceous times.

The **Vértessomló Siltstone Formation**, whhich has no outcrops, was deposited on the Lábatlan Sandstone probably with continuously or perhaps after a short gap in the east, and on the Tata Limestone in the west. The Vértessomló Siltstone (CSÁSZÁR 1995, 1996) is a formation of a semi-restricted basin. Lithologically it is a darkgrey marly siltstone with a varied pelite, sand and carbonate content and remarkable pyrite nodules of gel structure. The formation is featured by abundant planktonic foraminifers and ammonites. The maximum width of the facies zone is less than 10 km today. Its important drillholes are as follows: Agostyán Agt–2, Tatabánya Ta–1462, Vértessomló Vst–8 and Tata T–4.

Towards the west the Vértessomló Siltstone is replaced by the **Környe Limestone Formation** of Urgonian facies. It is subdivided into two members. The lower one consists of a biodetrital limestone of platform origin in allochthonous position (Kecskéd Member) and the upper one of an organogenic limestone in autochthonous position (Kocs Member). It is underlain mostly by the Tata Limestone. They can only be distinguished by thorough examinations. The distinction is based on biogenic constituents; the echinoderm (mainly crinoid) fragments are the prevailing biota in the Tata Limestone while rudist fragments dominate in the Környe Limestone. In the sequences the former one is gradually replaced by the latter one. In the Kocs Member in addition to the dominant rudist (Agriopleura, Toucasia) coquinas of chondrodonts, ostreids are common but coral and Chaetetopsis colonies are not rare either. Orbitolina is the most significant microfossil that may occur in rock-forming quantity as well. At the foot of the slope in the transitional zone towards the Vértessomló Siltstone often fragments of reef building organisms deriving from the platform can be observed. According to CSÁSZÁR (1995) the 13.5 metre-thick intercalation of the Kecskéd Member in the Vértessomló Siltstone (borehole Vst–8) can be considered as shelf margin sediment (SMST). The one-time width of the Környe Limestone of platform and platform slope facies did not go beyond 15 km running parallel to the Vértessomló Siltstone Zone. It has been well exposed in several drillholes: Oroszlány O–1825, –2547, Környe Kö–27, Kocs–1.

The **Tés Clay Formation** is a heteropic facies of the upper part (Kocs Member) of the Környe Limestone. It is a formation extending far beyond that in the SW direction. The transition between the two formations is manifested in their alternation. The formation of cyclic character consists of variegated and grey clay, clay-marl and marl beds. Limestones with mainly biogenic origin are also present in the formation in varied frequency but several sandstone and a few conglomerate intercalations also occur. Its fossil content corresponds to the extreme fluctuation of salinity. In the marine beds orbitolinae, brachiopods and sea-urchins, in the brackish-water beds mainly molluscs, while in the freshwater ones Characeae and Munieria are common. Ostracods occur almost equally in each facies. The formation of maximum 200 m thickness is dominated by variegated beds in the environs of Bokod (Bokod Member) that was deposited here mainly in delta and drying-out flood plain swamp environment (CSÁSZÁR, 1995). Its occurrence is south-west of Kocs in the axis of the syncline. Its surface outcrops are known in the Bakony Mountains only. In the relevant area the Tés Clay has been hit by several drillings: Oroszlány O–1722, 1751, 1825, 1828, 2384, Környe Kö–27 *etc.*

The second Urgonian level in the Transdanubian Range, also belonging to the Albian stage, is called the **Zirc Limestone Formation**. The present extension of the formation is bordered at Környe, in the north-eastern continuation of the Oroszlány Basin. It is developed from the Tés Clay, via the omission of clastics, with a fast transition. From among the three members of the formation the thick-bedded Eperkéshegy Limestone Member of basically rudistid biostrome origin occurs in the map area with its complete thickness (20–25 m). Only the lowermost beds of the following pelletal and microfaunistic member developed or preserved here in a less than 10 m thickness. On the map sheet it has been found by a few drillholes only (Oroszlány O–2348, –2396).

The youngest known unit of the more or less continuous Mesozoic sequence is the Upper Albian (to Lower Cenomanian) **Pénzeskút Marl Formation**, that only just appears as a small patch at the southern border of the sheet. The base of the formation is a dissolution surface developed on the top of the karstified Zirc Limestone Formation in connection with a considerable submarine gap (CSÁSZÁR 1995). The basal bed is a condensation horizon rich in glauconite. It contains also phosphatic nodules and ammonite accumulation suggesting a highstand, *i.e.* maximum flooding. Only the lowermost member of the three has avoided the erosion caused by a general uplift that followed the Cenomanian sedimentation. The nearly 500 metre-thick formation consists of grey, greenish-grey dolomitic marl with limestone-nodules and abundant ammonites, echinoids, benthonic and planktonic foraminifers, nannoplankton, dynocists and other palynomorphs. From among the few boreholes the Oroszlány O–2348 and the Pusztavám Pv–980 are the most important ones. (The latter is close to the border but out of the map sheet.)

The traces of the Upper Cretaceous sediments in this part of the Transdanubian Range are only represented by the nannoplankton and a few planktonic foraminifers preserved in the Tertiary formations. However, the moderate on-surface and subsurface occurrences of the **Budakeszi Picrite Formation** give evidence of a, however weak, Late Cretaceous magmatism. According to HORVÁTH [in CSÁSZÁR (1996)] the veins and subvolcanic bodies of varied alkaline mafic and ultramafic rocks belong here as well. In the Transdanubian Range their occurrence is restricted to the territory between the Velence and the Buda Hills within the Transdanubian Range. It appears on the surface at Budaliget and Nagykopasz in the Buda Hills and under the surface in the drillholes Alcsútdoboz Ad–2, Vál–3, Mány My–1 and in some others at Nagykovácsi. The silicocarbonatite, alkaline basalt and the alkaline meta-gabbro are their most frequent rock type.

The existence of various Cretaceous formations from the Csõvár–1 borehole within nappe structures has been reported by HAAS *et al.* (1997) These data may allow us to suppose similar setting in the north-eastern part of the Transdanubian Range, too.

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