JAHRBUCH DER GEOLOGISCHEN BUNDESANSTALT

Jb. Geol. B.-A. | ISSN 0016–7800 | Band 142 | Heft 4 | S. 521–533 | Wien, Dezember 2000

Danube Region Environmental Geology Programme DANREG — Explanatory Notes | Editor: G. Császár

Hydrogeological Map

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Introduction

The legend and the mode of construction of the DANREG hydrogeological map have been agreed at the meetings of Austrian, Hungarian and Slovak hydrogeologists. They comply for the most part with the UNESCO/IAH Convention of 1970 and with the methods of hydrogeological map construction (UNESCO *et al.* 1970, Struckmeier & Margat 1995).

Out of the wells used for water supply, due to the very great number, only those have been indicated which are of major importance. However, nearly all thermal wells have been shown. Almost all wells used to monitor confined water and karst water have been shown because their frequency carries relevant information on the accuracy of the map. Of the groundwater monitoring wells, each well with a long detection period is shown. The water bases for each water works in operation as well as each area considered as a potential for a prospective water supply opportunity are also indicated.

The hydrogeological setting of the area, shown on the DANREG hydrogeological map, is largely predetermined by the hydrogeological features of the Neogene and Quaternary sedimentary complexes, which underlie most of the region. The following features are shown on the DANREG hydrogeological map at a scale 1:200 000:
— type, or permeability of aquifers — by colours/7 tints,
— lithology of aquifers — shown by type and orientation of hachure/21 types.

The most important of all hydrogeological parameters shown in the map are the permeability and the lithology of aquifers. It should be noted that the primary objective is to characterize aquifers, that is, to show the hydrogeological quality of the most permeable complex when a lithostratigraphic unit includes alternating rock types of different hydrogeological qualities. These are divided, on the basis of their relative permeability, type of permeability (pore–fissure–karstic) and extent, into seven categories, each shown as a different basic colour. There are three degrees of pore permeability, or areal extent, respectively, two degrees of fissure permeability and two degrees allowing to classify the aquicludes in stratigraphic terms (Tertiary and younger, or Mesozoic and older, respectively):
— Hydrography, springs and karstic features: The drainage network, springs, or karstic features, respectively, are shown as lines or dots. The springs are classified after their yield, and in cases of thermal, or mineral springs, their increased temperature, or mineralization, are shown, as the case may be.
— Groundwater dynamics: Line markings are used to express the groundwater dynamics. Arrows show the flow directions, dotted lines are used for groundwater divides.
— Hydrogeologically important man-made objects: These are mostly the hydrogeological wells. Shown in the map are those wells, which have yielded any hydrogeological information, or served as potable water sources, or to monitor long run variations of the water levels and the discharge from surface streams.
— Mineral and thermal waters: These are marked in the map as dots. Besides, there are also symbols to show protection areas of drinking water and medicinal water sources.
— Tectonical parameters: Such are the lines indicating hydrogeologically significant faults, thrust planes and intense tectonic disruptions, which are important in terms of groundwater source acquisition.

Hydrogeological regional units

Practically all kinds of aquifers according to the type of permeability are present in the map. There are fissured crystalline hard rocks, karstified Mesozoic aquifers and porous aquifers of different stratigraphy and permeability value. We distinguish them first of all according to permeability type and then according to stratigraphy.

Aquitards and fissured aquifers

No rock can be considered to be absolutely impermeable. Considering the fact that the majority of aquicludes have some fissure-type permeability, we discuss both aquitards and fissured aquifers in one chapter. They differ in stratigraphy, but the main features are the same: intensive heterogeneity, fissure aperture closing downwards with resulting decrease of permeability, and improved hydraulic conductivity due to tectonic effects.

Crystalline rocks (crystalline schist, gneiss) in the Sopron Hills, Ruster Höhenzug, Leithagebirge, Hainburger Berge, and Malé Karpaty Mts are featured by a poor permeability. They contain gap water and fissure water only. Even the drainage effects of the mines in the Malé Karpaty Mts, particularly in the area of Pernek and Pezinok do not produce more concentrated groundwater outflows.

The Carpathian Keuper sequences of the Mesozoic units represent an aquiclude for the karstic waters ascending from the complex. The same can be stated about the Paleogene sequences consisting of sandstones and clays.

The Lower Cretaceous rocks in the N–NW part of the Gerecse Mountains consist of two groups of rocks with different hydrogeological features, found on or under the surface. The beds of the Lábatlan Formation, consisting dominantly of sandstone are featured by medium impermeability, while the dominantly clayey Bersek Marl is impermeable [Gyalog (ed.) 1996].

A coal-bearing sequence containing impermeable claymarl and clay beds is found at the base of an Eocene sequence of the Tertiary basins (Tatabánya, Dorog, Nagyegyháza, Mány and Zsámbék basins). Its hanging wall includes the “suspended karst water aquifer” Szõc Limestone, of excellent permeability. These beds outcrop at the marginal areas of the mountains, forming an infiltration area. At some parts of the area, they have a direct connection with the “main karst water aquifer”, due to structural setting. In the basement of the Tatabánya Basin —in accordance with the central zone of the syncline structure — there are Triassic, Jurassic, and Lower and Middle Cretaceous rocks. Out of the latter, the Környe Limestone which is also a "suspended karst water aquifer" is of hydrogeological importance. In the basement of the Dorog Basin, Triassic, Jurassic and Lower Cretaceous rocks are found, whereas the basement of the Nagyegyháza, Mány and Zsámbék basins is made up by Triassic carbonates.

In the Gerecse Mountains, the beds of the Oligocene Csatka Formation, featured by medium permeability and by rather varied lithology, clay, clay-marl as well as sand, sandstone with a varying grain size are of considerable extent. Due to a pre-Oligocene denudation, these beds often directly overlie the "main karst water aquifer sequence" consisting of Upper Triassic rocks. At the SE part of the mountains, the biogenic calcareous sandstone and sandstone beds excellent permeability, belonging to the Sarmatian Tinnye Formation are typical, also outcropping in a large area in the Zsámbék Basin.

In the Pilis Mts and Buda Hills, Oligocene rocks of varied lithological features are present. The Mány Formation consists of sand, clay and gravel. The Hárshegy Sandstone that comprises also subordinate argillaceous and coal-bearing beds, and the Buda Marl (marl and clay-marl) have a considerable areal extent. The latter two reduce the karst type infiltration in the surrounding area. Along the Danube, the impermeable beds of the Kiscelli Clay are of importance in which sulphatic groundwaters have been produced due to decomposition of the pyrite content of the clay. The Cserhát Hills are also built up by Oligocene (Tóth & Vermes 1984). East of the area of extent of the Garáb Schlier which is typical at the margin of the Börzsöny Mountains, and of the Budafok Formation, the Mány Formation featured by a varying lithology (sand, clay and gravel) and a medium impermeability is found on the surface, or in subsurface position. In NE, in a larger area, it grades into sand and sandstone. The impermeable Lower Oligocene Kiscelli Clay occurs in the eastern part of the map sheet.

The silica-cemented Hárshegy Sandstone of the Cserhát and of the blocks on the left bank of the Danube is heavily tectonized. Consequently it does not impede the infiltration towards underlying strata.

Towards the Pest Plain in S direction, the hydrogeological setting becomes more varied. The Fót Formation consisting of sandstone and calcareous sandstone has a considerable extent and rocks that appear on the surface on the right bank of the Danube also appear at a lower terrain position. In continuation of the Dunazug Mountains several occurrences of the Miocene Tar Dacite Tuff Formation are known, and S of it there are impermeable clay and clay-marl beds of the Miocene Baden Clay. At the southern margin of the map sheet, the calcareous sandstone beds of the Sarmatian Kozárd Formation are known, whereas in the SE corner, the Pannonian Basin marginal rocks of Great Hungarian Plain) appear. These comprise the impermeable clay-marl and lignite beds of the Late Pannonian Tihany Formation and the lacustrine clay and sand beds of the Zagyva Formation.

The Oligocene–Miocene, Miocene, dominantly sand and unconsolidated sandstone underlying rocks of the andesite sequence (Garáb Schlier and Budafok formations) of the Börzsöny Mountains are medium, here and there good, at other sites poor aquifers. They come to surface at the S–SE margin of this orographic unit. In the southern and western parts of these mountains, close to the surface, the foraminiferal clay-marl and clay beds of the impermeable Szilágy Clay Marl Formation overlies the volcanic sequence. It is from here that the beds of the Badenian Leithakalk (Rákos Limestone Formation) are known. These are of good permeability but appear in a small thickness and not contiguously; therefore they are of subordinate importance for hydrogeology.

The Neogene volcanic complex crops out in the eastern part of the area under study. In the east the sediments of the Ipeflská pahorkatina Highland fringe the volcanoclastics of the Krupinská planina Plateau, Börzsöny Mts and the Dunazug Mts (Kaszap 1976). The volcanic complex has a complicated groundwater circuit. It is possible to delineate within the area of Neogene volcanics a shallow subsurface groundwater circuit bound to the cover units as well as to the zone of increased jointing, in which the regimen is distinctly influenced by the climatic conditions. A part of groundwaters circulates down to 100–200 m, or even deeper, where the discharge regime of the structure reaches an equilibrium. The results of extensive drilling in the area of the Krupinská planina Plateau show that the groundwater sources with the greatest yields occur where the tectonic unrest played an important role, *i.e.* in the lower sections of streams. If the permeability of a rock body is enhanced by tectonism, the yields from wells at a number of places reach 20 to 30 l/sec. The permeability of the volcanic rocks show some zoning. Due to weathering and to the filling of pores with weathering products the permeability of the upper part of volcanic complex, down to a depth of 30–50 m, is lower. As a result, most wells have the yields below 5.0 l/sec. The Neogene volcanic region is poor in springs. Small strata-bund springs occur within the eroded blocks. There is a number of small scree exsurgences, which dry-up during the dry season. Their discharge only rarely exceeds 0.2–0.3 l/sec.

Karstic aquifers

The karst water stored in the Triassic —in Austria and Slovakia Middle Triassic, while in Hungary mainly Late Triassic— are of major importance from the viewpoint of drinking water supply due to extreme permeability and water storage capacity of those aqifers.

The carbonate rocks having a thickness of several hundred metres as proved, but of several thousand metres as estimated, represent a drinking water base of outstanding importance for Hungary. The original natural state has been strongly altered during the past decades due to a mining water withdrawal at a rate of 300 m^3/min performed in the Eocene coal basins. The karst water level and the piezometric pressure level decreased by 30 m on the average in the mountains, and by nearly 100 m in the mining areas. This caused, particularly along the major tectonic lines the major springs (Tata, Dunaalmás) uprushing along faults found at the hill margins to run dry, as well as the water output of thermal springs of thermal karsts in Budapest to decrease. In the early 90's, the mining activity was considerably reduced, and the restoration of the karst water system began. For the time being, there are only two brown coal mines —the Mány mine and the Lencsehegy mine near Dorog— where water withdrawal for mining safety purposes is performed, at a total rate of 36 m^3/min. Some water withdrawal pits established for mining purposes at Tatabánya and partly in Dorog were furnished with a regional drinking water supply network even during the period of coal mining, the replacement of which with local water bases is a current task.

From the regional point of view, we can find karstified carbonates in the NE part of the Transdanubian Range, where the elevated blocks of the Gerecse, Buda and Pilis Mts belong to the southern wing of the syncline. They are built up mainly of Mesozoic carbonates and form karst type infiltration areas, including the Tertiary basins located between them (SIPOSS 1988).

The Gerecse Mts is divided into three parts with regard to hydrogeology. The southern part of the mountains is built up by Upper Triassic, heavily crumbled Hauptdolomit of excellent water storage capacity. Its hydrogeological behaviour is often similar to that of a porous rock, being intensive fissured. The Upper Triassic Dachsteinkalk constituting the bulk of the middle part is outcropping or subcropping. This rock is of excellent permeability controlled by its karst type passage and cavity systems. These here and there form considerable caves primarily linked with tectonic lines (JOCHA-EDELÉNYI & GONDÁR-SÕREGI 1996). Over it —towards NW on the surface, in accordance with the general direction of striking, and in the separate Tata block— Jurassic carbonate rocks are known. They partly show a behaviour similar to that of Dachsteinkalk, and they partly have a poorer water storage capacity as compared to Dachstein Limestone, due to their argillaceous beds. The occurrences of freshwater limestone in a considerable extent and thickness at the N and NW parts of the Gerecse Mts originate from an important Quaternary hydrogeological event taking place in the area, namely a long-term spring activity. This has lasted even to date, being related to the uplift of the mountains (JOCHÁNÉ EEDELÉNYI & CSEPREGI 1994).

The Buda Hills and the Pilis Mts consist dominantly of dolomite and limestone beds. In the Buda Hills, in addition to the carbonate rocks of the Dachsteinkalk and the hauptdolomit Formations, also the several hundred m thick beds of the Middle Triassic Budaörs Dolomite play a considerable role in the "main karst water aquifer sequence". At the S–SW parts of both mountains, the well karstified, excellent aquifers belonging to the Upper Eocene limestone and featured by an abundance in caves of thermal spring origin (Pál-völgy, Szemlõ-hegy, Ferenc-hegy) [SCHMIDT (ed.) 1963] are known in a considerable thickness. The hydraulically uniform karst water aquifer formed in karst rocks are tapped along the Danube by lukewarm and warm springs resulting from fault lines and supplied with water dominantly from the deep karst. Their water output was negatively affected by water intake activities at Tatabánya, Mány and Dorog, through a common watershed formed in the Buda and Pilis Mts.

The occurrences of freshwater limestone originating from spring activities in the region of Budapest, and the Holocene alluvial deposits of the Danube forming a bank-filtered water base are of more than local importance from the hydrogeological point of view.

In the Mesozoic basement of the Dunazug Mountains, outcropping in a very small area at Esztergom only, Upper Triassic carbonate rocks are included. The recharge of karst springs at Esztergom is provided from the water catchment area in the Pilis Mts, along tectonic lines.

The blocks outcropping on the left side of the Danube, featured by a small areal extent, are built up from Upper Triassic limestone and dolomite, and of the Eocene limestone. A hydrological link is probable between the blocks. In their cover the silica-cemented Hárshegy Sandstone is included but its thickness is not considerable and it is heavily broken, therefore, it does not impede the infiltration. There are no springs near the basement blocks, and the infiltrating precipitation flows towards SE into the depth towards the Nagyalföld (Great Hungarian Plain).

In the Slovak part of the region, most important are the karst waters of the Middle and Upper Triassic carbonate aquifers in the Malé Karpáty Mts. Some springs and karst development are bound also to Lower Jurassic limestones. In the vicinity of Bratislava, in the areas of Propadlé (Jurassic — envelope), NE of Borinka and Píla there are small segments of these rocks, which drain the surface and the underground waters from the neighbouring complexes. The Mesozoic rocks, situated in tectonic position below the overthrusted crystalline rocks, account for the formation of karstic springs of several tens of litres per second discharge. A narrow strip of limestone and cherty limestone, stretching from Èastá to Horné Oreπany, is being dewatered by springs with a total yield of 32–94 l/sec.

The most important concentration of the karstic waters in this mountain range is bound to the Middle to Upper Triassic limestone-dolomitic sequences of the KríΩna and Choè Units. Between Kuchyòa and Loπonec the KríΩna Unit carbonates form a SW–NE striking strip, which dips steeply north-westwards to reach a considerable depth. They are underlain by the hydrogeologically unfavourable sequences of the envelope unit, mainly by marly slates and limy sandstones of Albian and Cenomanian age. Unfavourable Carpathian Keuper sequences of the unit proper represent an aquiclude for the karstic waters ascending from the complex. Such hydrogeological setting does not allow to assume a passage of karstic waters from the KríΩna Unit into the underlier of Tertiary sediments of the Záhorská níΩina Lowland. This carbonate complex occupies an area of some 20.6 km^2 and its dewatering, mainly into the Morava River, and partly into the Váh River drainage systems, takes place via springs and surface streams. A total discharge from this structure via springs is

153 l/sec and 48–70 l/sec pass via concealed discharge into the surface streams.

In the Austrian part of the DANREG area an important karstic aquifer is the Badenian and Sarmatian Leithakalk, too, which occurs around the Leithagebirge. This Leithakalk makes up with the accompanying Badenian and Sarmatian sands a single hydrogeological unit. The recharge can be explained mostly by infiltration of brooklets, which come from the crystalline core of the Leithagebirge and ooze away as soon as they reach the Leithakalk. This karstic aquifer provides for example the radial well of Purbach which is able to produce 50 l/sec.

Mineral and medicinal waters

At the northwest foot of the Hainburger Berge (Austria) which represent the southernmost branch of the Malé Karpaty Mts there is the thermal water occurence of *Bad Deutsch Altenburg*. It is connected with Triassic carbonates, within which the thermal water ascends from the bottom of the Vienna Basin (WESSELY 1983). The whole discharge of the thermal water is several tens of l/sec (GANGL 1990, p. 3.). The content of dissolved matter amounts to approximately 3200 mg/l, the content of H_2S to 15 mg/l (ZÖTL & GOLDBRUNNER 1993, p. 272.).

In the same way the thermal springs of *Mannersdorf* at the north-western foot of the Leithagebirge are connected with the occurrence of Triassic carbonates. The dissolved substances amount to approximately 1500 mg/l (ZÖTL & GOLDBRUNNER 1993, p. 268.).

In Edelstal —this village is situated in the south of the Hainburger Berge— there is the mineral water deposit of *Römerquelle*. The aquifer of this mineral water is Triassic dolomite and Pannonian sand. The content of dissolved matter runs around 1000 mg/l (ZÖTL & GOLDBRUNNER 1993, p. 279.).

The *Balf medicinal waters* that have been famous for centuries for the curative effect of drinking and bathing cures, break to the surface from groundwater springs welling forth at the SW corner of Lake Neusiedl/Fertõ). The six springs of low water output (6 to 22 l/min) are partly seasonal, giving sulphurous water. It is disputed whether the hydrogen sulphide is of postvolcanic or paludal origin, whereas carbon dioxide is clearly supposed to be postmagmatic. The sulphurous water springs include the springs called Mária-, Fekete- and Wolfgang-forrás, whereas the springs named Savanyúvíz I. and II. and István are hydrogen carbonatic. In the 70's, a couple of wells were drilled in order to check and control water withdrawal.

In Hegykõ village, a well with a depth of 1500 mm taps Tortonian clay-marl/sandy marl and Palaeozoic sericite-muscovite schist and calcareous phyllite, supplying a medicinal water with a high —8 g/l— salinity and characteristic sodium hydrogen carbonate content, a temperature of 57 °C and a considerable fluoride content [BÉLTEKY (ed.) 1965].

The *Igmánd medicinal water* is a bitter water with magnesium sulphate which has been produced from a depth of 4 to 8 m using 11 dug wells located between the villages Nagyigmánd and Kocs, in the valley of Csicsói-ér (Csicsó brooklet). This medicinal water is due to a special hydrogeological situation, namely, that the magnesium content of Triassic dolomite clasts originating from the Vértes is leached by the sulphatic groundwater due to decomposition of the pyrite in the Pannonian grey clay. In its original state the water has a magnesium sulphate content of 42 to 70 g/l which is, however, suitable for medicinal purposes only when diluted [SCHULHOF (ed.) 1957].

The karst water stored in the Upper Triassic rocks —featured by cracks and fissures— in the *Transdanubian Range* came to the surface through a number of famous spring groups during the period preceding the large-scale water withdrawal. Several wells were used to expose thermal water with Ca-Mg hydrogen carbonate content from beds at a depth of several hundred metres, and —in some places at a depth of one— two thousand metres.

At *Ács*, an outlet water flowing out at a rate of 1700 l/min at a temperature of 70 °C and having a dissolved matter content of 1120 mg/l was obtained from a dolomite filtered by Miocene limestone beds [BÉLTEKY (ed.) 1965].

At *Komárom*, an outlet water was obtained from Triassic rocks filtered by Miocene and Oligocene beds, flowing out at a rate of 2500 and 550 l/min, at a temperature of 60 °C and 40 °C, respectively.

At a part of *Tata*, named *Tóváros*, the karst water that infiltrated in the outcrop areas found in the Vértes and Gerecse Mts before the period of karst water level reduction, was flowing along major fault lines and broke to the surface in springs forming ponds. The 160 springs supplying the 17 smaller or larger ponds had a total water output of 130 000 l/min, at a temperature of 20 to 21 °C.

The *springs in Esztergom*, in the area between Kis-Duna-ág and Várhegy (Castle Hill) uprush within a circle with a radius of some 150 metres, are bound to major tectonic lines. They were used during the centuries for various purposes (to make horses or ducks swimming, Turkish bath, swimming-pool, slaughterhouse, then various forms of bathing). The water had a temperature of about 28 °C. The yield of these springs, an average of 200 l/min was linked with the water level of the Danube and eventually increased even to a tenfold value during a flood. A well drilled in the beginning of the 20^{th} century produced water flowing out at a temperature of 27 °C from Dachsteinkalk, with an initial yield of 3300 l/min [ˇKVARKA 1989].

In the *Lepence Valley (Visegrád)*, a water flowing out at a temperature of 38 °C, with an output of 480 l/min., was obtained from the andesite and from the tectonic zone in the cracked-fissured Dachstein Limestone underlying the Oligocene beds and the andesite. The water has a Ca-Mg hydrogen carbonate content, and a total dissolved solids (TDS) content of 1627 mg/l.

At *Leányfalu*, a water flowing out at a temperature of 45 °C, with an output of 560 l/min and a total dissolved matter content of 1161 mg/l was obtained from Triassic limestone. In the *Papsziget borehole (Szentendre)*, water flowing out at a temperature of 35 °C, with Ca-Mg hydrogen carbonate and a total dissolved matter content of 1472 mg/l was obtained from Eocene limestone and Triassic dolomite, with an output of 60 l/min only.

At *Ráckeve*, on the left side of the Danube, a water flowing out at a temperature of 61 °C, with an output of 10001 l/min and a total dissolved matter content of 812 mg/l was obtained from Pannonian sand at a depth of nearly 1000 m.

The *Budapest springs* supplied a daily amount of 40 million litres of warm and 30 million litres of lukewarm water before the period of an intervention into water circulation, along the zone where the areas of the Transdanubian Range which bumped into the depth and the Great Hungarian Plain encountered, through springs flowing out at the boundary between permeable and impermeable beds.

At the northernmost part of the Buda side, the Eocene and Triassic rocks in a Pünkösdfürdõ borehole supplied water at a temperature of 24 to 25 °C, with an output of 2000 l/min. At *Csillaghegy*, lukewarm water at a temperature of 19 to 22 °C is known, and the spring yielded 2000 l/min.

The boreholes drilled to a depth of several hundred metres provided an output of 150 to 100 l/min. The springs at Roman Bath break to the surface from the alluvial muddy sand beds of the Danube. The Romans used it as drinking water. It had a temperature of about 22 °C and at the site it broke to the surface calcareous tufa cones were found. During the 19th century, the springs had a total output of 7388 l/min. At present, as shown by measurements, it varies between 2500 and 7100 l/min and is considerably influenced by the water level of the Danube.

The springs and dug wells belonging to *Császár Spa* also took water from the alluvial sand beds of the Danube. The drilled wells penetrated into the Buda Marl. The water of 55 to 62 °C temperature has chloride, sulphate and hydrogen carbonate content. The springs of *Lukács Spa* have a temperature range from 27 °C to 64 °C. The sites where they break to the surface are in partly calcite-filled fissures of the Buda Marl. The chemical composition is similar to that of the Császár Spa water, but the contents of sulphate and chloride are at some sites are slightly higher. In order to compensate for a decrease in the yield of natural springs, a couple of boreholes supplying water at an output of 500 to 3500 l/min were drilled in both baths.

Boreholes on Margaret Island were drilled in order to capture “runaway” springs found in the Danube. The boreholes drilled into the Buda Marl and the Eocene limestone had a maximum output of 10 500 l/min and a temperature varying between 43 °C and 68 °C. The water has a chloride, sulphate and hydrogen carbonate content. Recently, the water obtained from a borehole drilled into Triassic rocks is being bottled for sale.

A borehole drilled at *Tungsram Spa* in Újpest has supplied water at a temperature of 24 °C, at a rate of 37 l/min, from Eocene limestone.

The wells supplying with water the *Dagály Spa* and a bath named Elektromos obtain it from a depth of 125 m and 250 m, respectively, from an Eocene limestone bed, at a temperature of 41 °C and 46 °C and at a rate of 6200 and 86 l/min, respectively.

The aquifer supplying *Széchenyi Spa* with hydrogen carbonatic water is a Dachsteinkalk found at a depth of nearly 1000 m. The water has a temperature of 76 °C and an output of 3200 l/min.

The *Pascal Spa* in the Zugló district of Budapest is supplied with a hydrogen carbonatic water of a temperature of 70 °C at a rate of 900 l/min, from a Dachsteinkalk hit at a depth of 1400 m.

Since the southern boundary of the map sheet crosses Budapest, several famous thermal water occurrences (such as the Rudas and the Gellért Spa and bitter water occurrences known in the SW part of Budapest are located outside it.

Porous aquifers

Due to extensive sedimentation in the subsiding Tertiary and partly Quaternary basins, many clastic deposits were generated, comprising also less permeable or even impermeable fine-grained sediments. Their vertical or lateral extent is varying fastly. Thus providing only limited possibilities for concentrated groundwater flow. But still there is a huge enough mass of coarse-grained sediments serving as an important groundwater source both in Quaternary and Tertiary units, of confined water type, unconfined type and bank-filtered type.

Porous aquifers in Tertiary sedimentary basins

Most of the region is underlain by a Neogene sedimentary complex. In the east of the Alpine–Carpathian arc there is the Pannonian Basin, within the Alpine–Carpathian arc lies the Vienna Basin. Both are filled with Neogene sediments. These basins were formed, as a result of intense tectonic downslip faulting, along their inner side. Their filling has in its deepest parts a thickness of several thousand metres.

These Neogene sedimentary complexes are composed mostly of unconsolidated strata of gravels, sands and clays. These are locally cemented by the calcium carbonate to form conglomerates, calcareous sandstones or organogenic limestones. The Neogene sediments lie predominantly horizontally, or dip at an angle of up to 10°. Their thickness in both the Vienna and the Pannonian basins, increases towards the basin centres. The maximum thickness of the Neogene cover in these basins reaches even 5500 m. Both areas were subject to several marine transgressions and regressions.

Alternation of non-permeable clays with permeable sands and gravels and their basin configuration causes groundwater levels to become confined and to acquire either a positive, or a negative piezometric level. The blocky structure of the basin filling, the granulometric composition of sediments and their thickness and depositional setting influence, in addition to other factors, the circuit and the recharge of groundwater in the permeable Neogene sediments.

Individual artesian horizons have only rarely a yield of 10 l/sec, in most cases only 1–3 l/sec from one well.

Several concomitantly pumped horizons may produce a yield of up to several tens of l/sec.

Vienna Basin

In Austria the following geographic sectors of the Vienna Basin are comprised by the DANREG region: North of the Danube there is the Marchfeld; south of the Danube there are the Rauchenwarther Platte, the Arbesthaler Hügelland, and adjacent to them the north-eastern end of the Mitterndorfer Senke.

The Marchfeld and the Mitterndorfer Senke are covered by mighty Quarternary sediments. By way of contrast in the Rauchenwarther Platte and the Arbesthaler Hügelland —both lie about 50 m above the Marchfeld and the Mitterndorfer Senke— the Pannonian underground is screened by a more fragmentary Quarternary cover of gravels and loess. The Lower Pannonian is mainly build up by sandy-clayey sediments, the Upper Pannonian includes mostly clay-marl. Therefore these Tertiary sediments can be used for local water supply only.

On the eastern margin of the Vienna Basin, on the slopes of the Leithagebirge and the Hainburger Berge as well as in the Brucker Pforte which is situated in between, not only Pannonian but also Sarmatian and Badenian sediments crop out. These consist mainly of gravel, conglomerate, Leithakalk, sand, sandstone and marl, respectively clay marl. They are —above all the Leithakalk— of great importance for the water recourses management in this region (compare chapter “Karstic aquifers”).

The Mattersburger Becken (also called Eisenstädter Becken or Wulkabecken) which is bounded by the Leithagebirge, the Ruster Höhenzug, and the Soproni-hegység (Sopron Hills) is also a part of the Vienna Basin. In the central region of the Mattersburger Becken Pannonian sediments from below a gappy Quarternary overburden. The Pannonian is underlain by Karpatian, Badenian and Sarmatian formations, which crop out in the marginal regions of the basin. These include gravel, conglomerate, sand, sandstone, Leithakalk, and marl, forming a permeable complex, whereas the very low permeability Pannonian sediments (mainly sandy clay) form an upper confining bed.

As generally known the pre-Neogene basement of the Vienna Basin is strongly structured (Kröll *et al.* 1993). In Austria the deepest part is situated east of Vienna; there the Schwechat depression reaches more then 5200 m beneath sea level. Further structures within the project area are the Gr. Engersdorf, the Marchfeld, the Lassee, and the Mitterndorf depression as well as the Aderklaa–Matzen, the Zwerndorf–Vysoká, and the Enzersdorf Highs. From oil exploration it is well known that in the central region of the Vienna Basin the mighty Tertiary sediments contains mainly stagnant saline groundwater (Wessely 1983). Only at the margins can be expected a deeper circulation of less saline groundwaters. As recharge area one can presume mainly Triassic carbonates but also Leitha limestones, Miocene gravels and sands which crop out at the margin of the basin.

On the basis of its tectonic setting the eastern marginal part of the Vienna Basin on the Slovak territory has been divided into several units:

The marginal blocky region of the Malé Karpaty Mts, composed of slightly waterlocked Badenian sediments, overlain by Quaternary sediments (proluvial, fluvial and deluvial sediments) of small thickness. We presume that within the marginal blocks area of the Malé Karpaty Mts there is a hydrogeological continuity between the Lower Badenian gravels and the marginal Mesozoic deposits. The Upper Badenian, represented by clay, sand and sandstone, is hydrogeologically insignificant.

Situated between Marchegg and Plaveck″ Mikuláπ, the Zohor Depression is a distinctly sunken, 7–8 km wide and some 36 km long graben, limited by faults. Two highs (the RohoΩník and the Lozorno ones) divide it into three partial depressions (Soloπnica, Pernek and Zohor–Marchegg depressions). The depression is filled by Quaternary sediments, which are of great hydrogeological interest. They are underlain by Dacian sediments. Several aquifers located in Dacian sediments (sands and gravels enclosed in clays) have been intersected in the Zohor depression by deep hydrogeological wells. This groundwater is characterised by artesian overpressure.

In the Plavecká depression Sarmatian and Pannonian sediments underlie Quatenary deposits. West of the line connecting Plaveck″ Mikuláπ with Plaveck″ Peter the Quaternary in the Plavecká depression is underlain by Sarmatian and Pannonian sediments. Since the clayey sequences outnumber the beds of sands, sandstones and gravels, these sediments are of little hydrogeological interest. The Lakπár High is a Neogene horst. Also the Láb–Malacky Horst consists of Pannonian and Pontian sediments.

The Kúty (Suchohrad–Gajary) depression is filled by Dacian sediments (clays with abundant sand beds), overlain by Quaternary sediments. The following Lakπár High is made up by Neogene (Karpatian) formations, overlain by thin Quaternary sediments. Less widespread are conglomerates and sandstones with calcareous clay intercalations. The conglomerates and sandstones are fissure aquifers. The central part of the high is made up predominantly by calcareous clays. The hydrogeological wells drilled in this area were negative. The younger Neogene sediments (Upper Badenian and Sarmatian), which occur in the western part of the high, are of no hydrogeological interest. The artesian wells have produced small yields (0.01–0.45 l/sec).

The Láb–Malacky Horst is an area of limited hydrogeological interest. The Pontian rocks are represented by clays with fine-grained sand intercalations and lignite seams (the Èáry Formation). It is general in this tectonic unit that the Neogene represents an impermeable footwall of the Quaternary fluvial and eolian sediments.

The Neogene rocks of the Suchohrad–Gajary depression are Dacian and Pontian sediments. They are overlain by Quaternary sediments. Outcropping are variegated clays, locally with gravels and sands (Gbely Formation) and limy clays with sand and lignite intercalations (Èáry

Formation). The clayey character of the formation, with sand beds, was favourable for the formation of artesian water horizons with, however, predominantly negative water level. Their number influences the yield of wells, which ranges from 0.2–2.0 to 5–10 l/sec.

Petroleum and natural gas, bound to the Upper Sarmatian horizons of the Vienna Basin, spoil the groundwater quality in this formation already at depths of 100–120 m. The yield of artesian horizons, tapped by a well, is some 6 l/sec, but locally even more. The best aquifers occur in the Upper Pannonian beds, composed of sand and locally of fine gravel.

Pannonian Basin

With regard to the tectonic setting the Austrian part of the Pannonian Basin can be divided into the Neusiedler Bucht and the Landseer Bucht. The Neusiedler Bucht which includes the Heideboden, the Parndorfer Platte, and the Seewinkel is mainly filled with mighty Pannonian sediment. Their thickness increases toward the east. The deepest part of the Neusiedler Bucht reaches 3600 m beneath sea level (Kröll *et al.* 1993). The Parndorfer Platte —to the north it is limited by the Leitha Valley— lies about 50 m above the surrounding plains. Its Tertiary substratum is covered by older Pleistocene gravel. Contrary to this the Tertiary of the Heideboden and the Seewinkel is mainly overlain by younger Pleistocene gravels. Within the Tertiary sediments of the Neusiedler Bucht the groundwater flow velocity is in general very slow. In the area of Neusiedl and Gols numerous artesian wells should be mentioned (Tollmann 1985, p. 545).

In the Landseer Bucht (Oberpullendorfer Becken) occur mostly Pannonian sediments, overlain by a Quaternary overburden, mainly loess. These Pannonian sediments consist chiefly of sands and make up an utilizable aquifer.

On the southern slope of the Sopron Hills crop out also gravels, Sarmatian marl, and Badenian sediments which are composed of Leithakalk, sand, and marl. In Deutschkreuz the mineral water "Juvina" is being produced from such Badenian sands. Its water temperature is about 15 °C. This shows that this mineral water is ascendent (Zötl & Goldbrunner 1993, p. 218.).

In the Slovak part of the Pannonian Basin, most of the Quaternary cover is underlain by Pliocene sediments, only the marginal parts are floored by Miocene rocks. Lithologically, clayey sediments prevail, with moving sand beds. The uppermost part of Neogene —the Dacian-Rumanian— is composed predominantly of sand, gravel and clay.

From the hydrogeological point of view, the lowland represents an extensive, indistinctly articulated artesian structure. The Dacian and Rumanian combined with the Quaternary sediments form a common unconfined groundwater reservoir. Owing to the deep entrenchment of Miocene sediments (to a depth below 100–2000 m), the hydrogeological features of the natural waters are essentially determined by the Pannonian, Pontian and Dacian formations. However, the aquiferous complexes are, in general, only moderately watered and the groundwaters are bound to relatively smaller, for the most part, up to 10 m thick sand beds. These are too indistinctive to allow for their monitoring from a greater distance. In the Subcarpathian region the Quaternary is underlain by Pannonian sediments. In the central depression there are outcrops of Dacian and Rumanian sediments, which constitute, together with the Quaternary ones, a single aquifer with free surface. In its deepest part— in the Gabèíkovo depresion (Gabèíkovo, Baka) the thickness of Dacian and Rumanian sediments attains 520–600 m.

A complicated geological-tectonic setting of the broader surroundings of Komárno (southern parts of Nitra and ≥itava drainage systems and of the Váh–Danube confluence) has its bearing on a complicated hydrogeological setting of this area. Tectonically shaped, lower, or higher highs of Neogene rocks alternate with troughs filled with Quaternary or Rumanian sediments, respectively. Northwards, the area centred around Kolárovo forms the extensive Kolárovo depression (100–120 m) filled with Rumanian, Dacian and Pontian sediments. These are sands, locally with fine gravel and with plenty of calcareous-sandy concretions. The Kolárovo beds are underlain by Upper Pannonian sediments. A characteristic feature of the area east of Komárno (Kravany–Chflaba) is that the Quaternary sediments east of the Kravany fault are underlain by Neogene volcanics and Paleogene rocks.

In the Fertõmellék Hilly Land there are good aquifers: the Sarmatian gravel and sand strata the water of which is utilised by the wells at Csalánkert and Tómalom whereas the Badenian and Sarmatian limestone beds are utilised by the Fertõrákos Water Works. The Badenian Clay Formation is impermeable. The Lower Miocene "Ligeterdõ" and "Brennberg" gravels are not important from the hydrogeological point of view due to their minor water recharge and small areal extent. In regard to hydrogeology, the Lower Pannonian rocks are less important than the Sarmatian ones, but both sequences are featured by a positive pressure. In regard to water exploitation, the confined waters of the Upper Pannonian that can be found at a greater depth are of greater importance. The sandy beds found in the range of 40 to 200 m have the best water supply capacity. The regional groundwater flow directions are from Seewinkel towards S–SE and from the Sopron–Vas Plain towards N–NE, towards the Hanság Main Channel as the direction of groundwater erosion base for the wider environment. The pressure level in the Pannonian aquifer sequence drops from a value of 150–160 m above the Baltic to a value of 115 m NW of the Sopronkövesd–Pereszteg Line. Thermal water can be produced from a depth of greater than 800 m, from Miocene or Pannonian beds overlying the Palaeozoic (Petõháza — 71 °C, Hegykõ — 57 °C) [Bélteky (ed.) 1965].

A part of the northern foreland of the Transdanubian Range which is shown in our map has a uniform hydrogeological setting. The Bakonyalja–Vértesalja area, then further on, the major part of the Komárom–Esztergom Plain stretching as far as the Danube are areas of Pannonian deposits with a great thickness, overlain by thin Quaternary deposits only. Its thickness is 4000 m at the Rába Line, or at the sites where it has a surface, or subsurface position and becomes gradually thinner towards E as far as the Dunazug Mts and towards SE towards the Bakony–Vértes Mts, that is, the basin margins. The Late Pannonian sequence which is better in regard to water supply capability has a thickness of 1000 m at Ács and also becomes thinner towards the margins. At Tata, it is only 100 m thick. It is also built up dominantly by clay-marl. The intercalated sand beds are of medium, or poor water supply capacity. Nonetheless —for lack of a better— they are tapped by the major part of the wells in a depth range of 50 to 200 m.

We have only a few data on the water supply capacity of the Miocene strata. A larger amount of water can only be produced from them at the sites where they are also recharged presumably from the underlying Mesozoic karst. Such sites are the thermal wells at Bábolna and Komárom.

Quaternary porous aquifer

The Quaternary clastics offer an excellent opportunity to produce water when the have sufficient thickness and effective porosity — even at a specific flow rate of 2000 l/min (33 l/sec), and in some cases even 12 000 l/min (200 l/sec).

Vienna Basin Quaternary cover

As mentioned above in Austria considerable parts of the Vienna Basin are overlain by mighty Quaternary sediments. In the Marchfeld the Quaternary gravel has an average thickness of 10 to 20 m (Schûgerl *et al.* 1984). In areas of stronger synsedimentary subsidence —such as the the Marchfeld Depression and the Lassee Depression— its thickness reaches more then 50 m. In the southern part of the Marchfeld the groundwater recharge is due mainly to infiltrating Danube water. A tract with a width of about four kilometres is influenced by the water level fluctuations of Danube. Here the waterworks of Lobau is situated, which makes an important contribution to the water supply of Vienna — this waterworks is able to produce 1000 l/sec. In the northern part of the Marchfeld the groundwater is being recharged mainly by precipitation. The near-surface groundwater is used mainly by agriculture, which has a high water demand to irrigate the fields. Therefore the groundwater level has sunk considerably.

The Mitterndorfer Senke is the most important groundwater body of the Vienna Basin. Its Quaternary gravel and sand sequence reaches a thickness up to 150 m (Berger 1989). Within the DANREG area —it includes only the north-eastern end of this Quaternary aquifer— its greatest thickness amounts about 30 m. In the Mitterndorfer Senke there are situated several important waterworks.

Since toward the North-east the Quaternary aquifer of the southwest-northeast oriented Mitterndorfer Senke becomes more shallow, in the North-east the groundwater discharges. The recharge is mostly done by infiltration of rivers which come from the highly humid Alps.

In the area of the Rauchenwarther Platte and Arbesthaler Hügelland the Tertiary is covered by a Quaternary overburden: Pleistocene aeolian deposits and gravel plains. As a consequence there are more local groundwater bodies of lower productivity.

The Quaternary filling in the Slovak part of Vienna Basin is divided into several neotectonic basins and relatively uplifted structures.

The *marginal, blocky area of the Malé Karpaty Mts*, composed of Quaternary sediments (proluvial, fluvial and deluvial sediments) of small thickness and of regionally low degree of permeability.

The *Zohor depression*, between Marchegg and Plaveck″ Mikuláπ, is a distinctly entrenched, tectonically limited graben. Two partial highs (the RohoΩník and Lozorno highs) divide it into three partial depressions (the Soloπnica, Pernek and Zohor–Marchegg depressions). It is filled by Quaternary sediments, which are of great hydrogeological interest. They are underlain by Dacian sediments. In the Soloπnica reservoir the thickness of aquiferous Quaternary sediments ranges from 29.0 to 78.0 m. The Quaternary sediments in the Pernek groundwater reservoir attain a thickness up to 120 m. In the Zohor–Marchegg reservoir the thickness of gravels and sands varies between 48.0 and 103.0 m.

In the Plavecká Depression larger amounts of groundwater have been documented, originating solely from concealed groundwater transfers (62.8 l/sec) from the Malé Karpaty Mts, into the lowland. The Quaternary is underlain by Sarmatian and Pannonian sediments.

The *Lakπár High* is a Neogene horst. The Quaternary sediments are 8.5 to 22.0 m thick. A complex of eolian sands represents an independent hydrogeological structure overlying the Karpatian formations, which serve as an impermeable floor to the eolian sands. The footwall of eolian sands is situated above the local erosional base. The water is supplied exclusively by the precipitation.

The Quaternary *terrace gravels of the Morava River* situated on the Láb–Malacky Horst, with local eolian sand cover (thickness 5–15 m), are not distinctly aquiferous. This due to their being located high above the erosional base. The Quaternary sediments of Kúty represent another hydrogeologically important complex. In the hanging wall there are clays with the Dacian sandy intercalations, which are also profusely aquiferous. Favourable hydrogeological conditions have been observed in the Myjava River alluvium, between the villages Senica and ˇajdíkove Humence (yields of wells 10–12 l/sec), near the Myjava–Morava confluence.

Danube River drainage system

The Danubian deposits (gravels and sands — alluvium in the area between Devín and Bratislava) in this area are 2 to 18 m thick. They are overlain by inundation loams. The substratum consists of Sarmatian clay and granodiorite. The direction of groundwater flows, as well as of groundwater levels are in perpetual interplay with the water level in the river and in its deviation channel.

The *PetrΩalka* area is characterised by a smaller thickness of fluvial gravels and sands (some 10–20 m), which overlie the Lower Pliocene clayey-sandy beds. The aquiferous gravels and sands have good permeability. The water quality is at risk due to the extensive urban agglomeration of PetrΩalka.

The features of the *Èuòovo area* are very favourable for the accumulation of groundwater. The permeability of fluvial sediments in this area have the highest mean values of the transmissivity coefficient T in Slovakia, with values of filtration coefficient of up to 4.10–2 m/sec. The average thickness of groundwater body is 100 m and the mean permeability coefficient of 4.10–3 m/sec, is very high.

The *Podkarpatská* (Subcarpathian) *area* on the left hand side of Mal˝ Dunaj: the Quaternary is represented by deluvial sediments, older Quaternary Danube terraces and recent Danube River deposits, whose thickness increases towards SE from 3–7 to 10–12 m. The extensive urban reconstruction and development of Bratislava precludes the use of alluvial waters. Farther eastwards, the extraordinary thickness (over 100 m) of well aquiferous gravels and sands near Jelka provides good hydrogeological preconditions for groundwater accumulation.

The *≥itn˝ ostrov region*. The geological-tectonic structure of the ≥itn˝ ostrov Island is not homogeneous. Due to tectonics the thickness of Quaternary sediments increases towards the centre of the ≥itn˝ ostrov Island. The aquiferous complex consisting of Quaternary to Rumanian gravels and sands is the thickest in the area of Gabèìkovo and Baka (520–600 m).

The *Gabèíkovo depression* is an independent hydrogeological region characterized by apeculiar geological setting, amount of accumulated water and groundwater regime. The groundwater regime depends on the discharge from the Danube and Little Danube and from precipitation. Recent hydrogeological research into the regime of this area has proved that this phenomenon is very complex. The pressure changes, brought about by large amounts of water, by height of the water column and by the irregularity of the horizontal and vertical distribution of variably aquiferous (because granulometrically different) sediments, predetermine the regime at the surface and at depth. In the Gabèíkovo depression the surface regime, with all signs of common groundwaters from Quaternary alluvia, takes effect to a depth of some 30 m. Below this limit the influence of deep regime becomes evident with all its dynamic features.

The aquiferous alluvium under the vaste ≥itn˝ ostrov Island represents a groundwater reservoir storing more than 10 billion m^3. of relatively good quality water. The dynamic discharge throughout the ≥itn˝ ostrov profile is estimated at 8 m^3/sec of water.

The *area of broader surrounding of Komárno/Komárom*. This area is geologically and tectonically very complicated, with higher, or lower highs of the Neogene sequence and with depressions filled by Quaternary, or Rumanian sediments, respectively (Kolárovo Member). The thickness of Quaternary deposits ranges from 8 to 20 m. The Quaternary is underlain by Neogene (Pontian–Rumanian) sediments. The Kravany fault truncates the whole structure to the east. Beyond this fault the Quaternary is underlain by the Palaeozoic, or by Neogene volcano-sedimentary rocks.

The *Kolárovo Member* (Pontian–Rumanian) fills the depression between Kolárovo and Èalovo. There, the aquiferous Quaternary sediments directly overlie the also aquiferous Upper Neogene sands and combined they form a single hydrogeological structure with freatic surface. The thickness of aquiferous sediments reaches 100–120 m. The groundwater regime in this area is influenced by the Danube and its tributaries — Váh, Nitra and Mal˝ Dunaj, as well as by a system of dewatering channels.

The *Kravany-˘túrovo region.* The older Danubian terraces and the Holocene alluvial plains are composed of Quaternary sediments. The terrace sediments are 10 to 15 m thick. At their base there are well permeable aquiferous gravels and sands. The terrace groundwaters are recharged solely by precipitation water. At the terrace margins there are springs with yields ranging from 0.2 to 5.0 l/sec. The Holocene alluvial plain stretching along the Danube River is a low-lying, locally marshy plain. The thickness of sediments reaches 5–12 m, while the thickness of the aquiferous gravel and sand bed is 4–10 m. The groundwater is directly influenced by the water level of the Danube.

Concerning the Austrian part of the Pannonian Basin —as mentioned above— in the *Neusiedler Bucht* mighty Quaternary gravels are widespread. The Tertiary floor of the Parndorfer Platte is covered by older Pleistocene gravels about 10 m thick. In the Heideboden and the Seewinkel the Tertiary is overlain by younger Pleistocene gravels with an average thickness of about 20 m, which increases toward the east and reaches 50 m at the Hungarian border. The gravels of Heidebodens and Seewinkel make a relatively good aquifer (Gruppe wasser 1996). Mainly in the Seewinkel its groundwater is intensively used by agriculture. Because in the Seewinkel the groundwater recharge is predominantly done by precipitation, it often comes to water shortage.

The *Sopron Basin,* situated in the westernmost part of both Hungary and the Pannonian Basin, the Pleistocene gravel cover of 3 m average thickness, overlying the Badenian clay, is the best aquifer. It is covered by a fine-grained alluvial deposit. In the entire area named Alpokalja ("foothills of the Alps"), it is there that the largest continuous groundwater stock is found which is also replenished by groundwater from side valleys. A part of the Sopron–Vas Plain is formed by the alluvial fan found between the Ikva and Répce brooks, the material of which was transported by the rivers from the Alps to the Pannonian terrain in the Pleistocene. This groundwater aquifer is 5 m thick on the average, attaining even 10 m in the river valleys, along with the Holocene deposits. Any considerable stock of water that can be exploited is only found in the valleys. Complicated flow conditions prevail between the valleys, on the ridges, due to a variation in grain structure, and the groundwater — practically blocked at the Pannonian terrain level — is stored in the Quaternary deposits.

The *Gyõr Basin* is an asymmetrical Quaternary sedimentary basin with an axis that is roughly perpendicular to the Rajka–Gyõr Line. It is bordered by the Rába fault Line in SE. Geographically, it can be divided into several subregions such as the Fertõ–Hanság Basin, Rábaköz, Szigetköz, *etc.* It is a Quaternary fluvial clastic sequence which attains a maximum thickness of 700 m at Szigetköz being adjacent to Csallóköz. It consists of various types of clastics but the enormous amount of stored water forms an integral hydraulic system. This can be concluded from the close connection between aquifer levels of the basin, featured by varying position in space and varying lithological facies. The flow and pressure conditions of this enormous stock of water are controlled mainly by the Danube. In the area called Szigetköz, the connection between the Danube and the groundwater can be studied through a water level period of 30 years for eight well series perpendicular to the Danube. Further well series were made later for which a shorter detection period is available but they make the analysis of the connection more complete. The Quaternary clastics offer an excellent opportunity to produce water — at a specific flow rate of 2000 l/min, and in some cases 4600 l/min— in the area of the entire basin, at various depth ranges. In most cases, a well does not produce water from a depth exceeding 100 m because quality is already accompanied by proper quantity by that depth. The regional flow of groundwater points, in the north, from the Rajka–Bratislava region towards SE, and from the southern area towards NE, that is, from both directions towards the Hanság Main Channel and the River Répce, reaching the Danube Valley through these depressions at the Mosoni-Duna/Gyõr–Duna axis (Magyarország...1989).

The region called *Hanság* should be specially emphasized as an area which is peculiar in many aspects and has a low terrain level. It lies by 50 to 60 m deeper than the Alpokalja and it joins the shallow marshy Lake Neusiedl/Fertõ Basin. At this site, the groundwater practically flows in the gravel bed which is thin there. It is overlain by alluvial sand, mud, peat and peat mud in which the water level has a subsurface position of 0 to 2 m. Its stock of water originating from precipitation and from the gravel bed with the high terrain level is controlled by the channel system. As concerns water circulation, brief periods are dominant.

In the western wing of the Gyõr Basin, in the southern margin of Lake Neusiedl/Fertõ, the water supply capacity of the Quaternary beds is lower due to the fact that they become thinner and have a finer granulometry. There, water is taken from the Late Pannonian shallow confined aquifer (Boroviczény *et al.* 1992).

A Quaternary deposit of greater hydrogeological significance in the northern foreland of the Transdanubian Range is only found in the Danube Valley and at a section between smaller and larger bays connected with the Danube such as the Komárom–Almásfüzitõ one. At the Gyõr–Almásneszmély section, several older Pleistocene fluvial terraces, or terrace debris are found. These — except for those that are in a direct connection with the river water— are of minor hydrogeological significance, due to their areal extent and position. The regional flow direction of groundwater points towards the River Danube.

Along the Danube, its terrace formations of various age and terrain position are important aquifers. The alluvial deposits at Szentendre Island supply a water base for the northern part of Budapest.

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