

# Budapest

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**Abstract** Budapest is situated in the Carpathian Basin close to Central Europe. It occupies 525 km<sup>2</sup> and has a population of 1.7 million. Although the city is built on one of the oldest hominid settlements in Europe, it was not given its present name until 1873 when it was formed by the merging of Buda, Obuda and Pest. The city is divided by the Danube river, which flows from north to south and contains two long islands—Szentendre to the north and Csepel to the south. The solid geology of Buda (on the right bank of the river) is predominantly limestone and dolomite, which form a series of hills and valleys, whereas Pest comprises the Danube floodplain, which overlies the Triassic deposits. The varied geology and geomorphology have given rise to a wide range of habitats, including mountains, lowlands, forests, arable land, wetland and the biggest river in Europe, Danube. The face of Budapest has changed rapidly throughout its history with periods of expansion being punctuated by conflict. There is very little information about the fauna before the eighteenth century, which is restricted to observations and anecdotes in the dailies or hunting magazines. There are two large reviews of the fauna of Budapest, one published in 1879, the other in 1942. The chapter lists the 107 vertebrate species that have been recorded in Budapest in recent times: 33 fish, 10 amphibians, 16 reptiles and 48 mammals. Most of the urban mammal species are common, small-to midsized generalists. The diversity and easy availability of food resources and shelter and the low number of predators and competitors compensate for the fragmented pattern of habitats and human disturbance. The future of urban mammals very much depends on the quality of ‘green’ spaces and the corridors between them.

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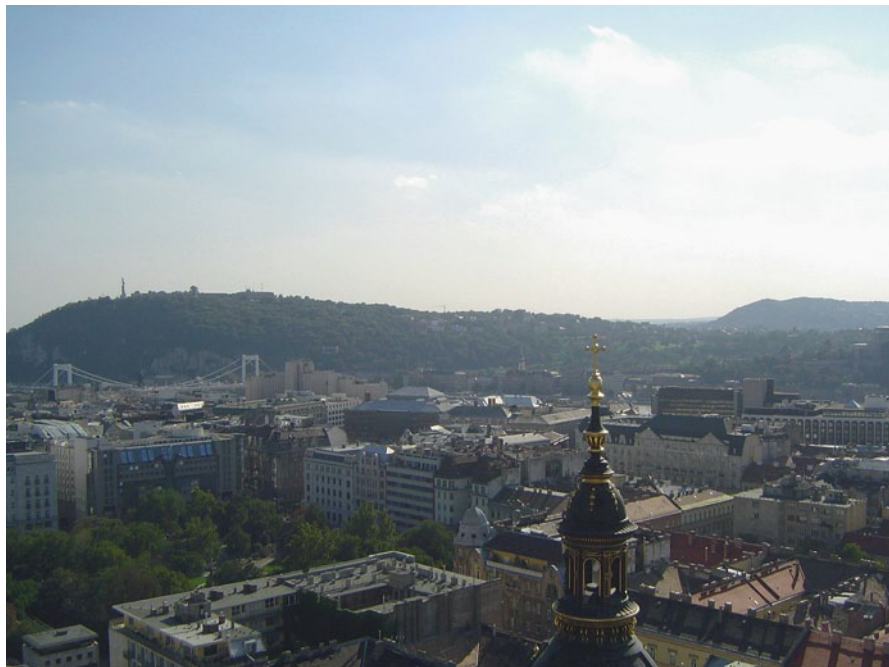
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## Location

Budapest is situated at 47°29'N, 19°9'E in the Carpathian Basin just south of the Central Europe and close to central Hungary (Fig. 1). The city, which occupies 525 km<sup>2</sup> and has a population of 1.7 million people, is the 11th largest European capital city and the 13th largest urban conurbation in Europe. It is divided by the Danube, which flows through it from north to south. A diagrammatic plan of the city is given in Fig. 2.

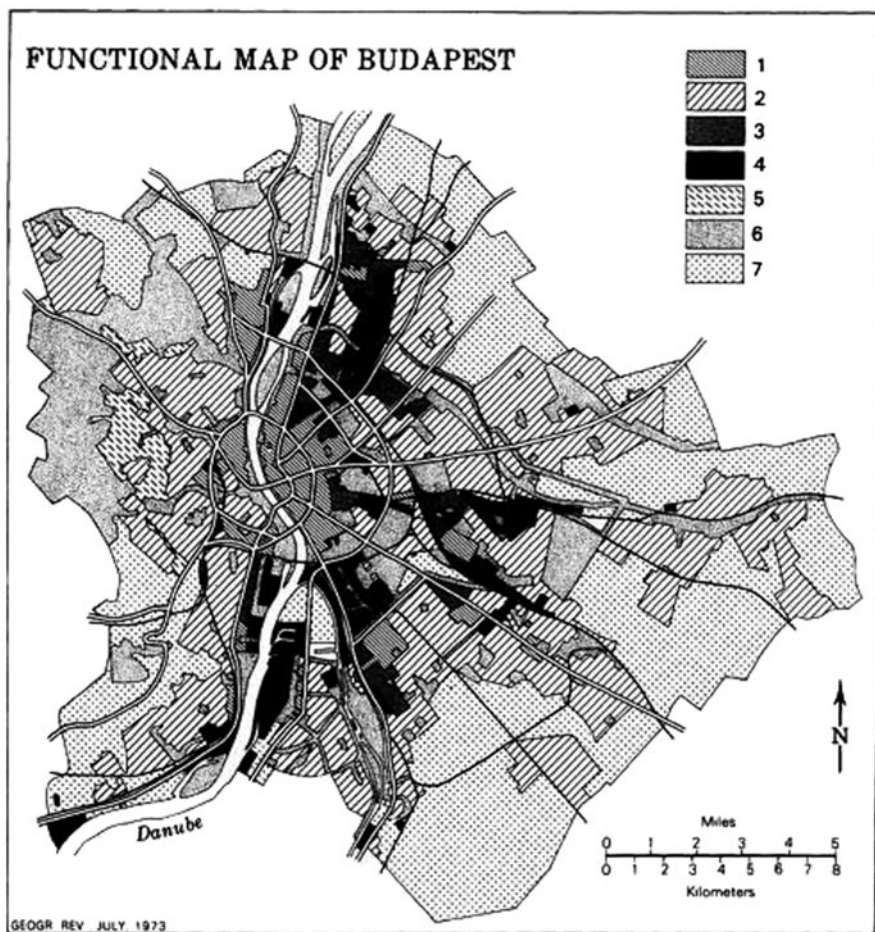


**Fig. 1** Budapest—view from the Szent István Bazilika (Dome). (Photo: Tóth-Ronkay)

## **Geology, Geomorphology/Topography and Soils (Szabolcs Leél-Őssy)**

Budapest is situated on two very different geological areas separated by the Danube river, which crosses the Carpathian Basin.

The Triassic rocks located several hundred metres to a kilometre below Pest (on the left side of the Danube) are generally covered by more recent argillaceous and sandy sedimentary layers of the Tertiary Period. The Szépvölgy Limestone, which lies discontinuously under the Pest Plain, is only a few tens of metres thick. The Buda Marl (an Eocene/Oligocene deposit) is several hundred metres thick. The most significant Oligocene deposit is the Kiscell Clay, which is several hundred metres thick. Exposures of the Rákos Limestone, which was formed about 16 million years ago, occur in Köbánya's Old and New Hills. The limestone was mined by deep workings in the eighteenth century, creating a network of tunnels; when mining stopped, most of the tunnels were used as beer cellars and sometimes for growing mushrooms—now they are mainly unused. Nearer to the surface, Pleistocene sands and gravels deposited by the Danube can be found. In the southeast part of the city, quartz gravel was mined for construction purposes, and some of the mining areas are being gradually occupied by the expanding town.



**Fig. 2** Diagrammatic plan of Budapest (after Pécsi and Sarfalvi: *The Geography of Hungary*, 1964)

The oldest rock on the Buda side (on the right side of the Danube) is the Budaörs Dolomite, which contains the remains of fossil plants. A little younger is the Mátyás Hill Formation, which contains flint nodules. Other Triassic deposits are the Dachstein Limestone (on the János Hill) and the Main Dolomite (on the Gellért Hill). As a result of tectonic movements or erosion, no younger Mesozoic deposits are known to occur. Marine transgression during the Upper Eocene (after 160 million years) resulted in the deposition of about 5–10 m of clastic, abrasive material, which is exposed on the Gellért Hill. Overlying this deposit is 40–60 m of the Szépvölgy Limestone, which is characterized by Foraminifera (e.g. *Nummulites*). The Szépvölgy Limestone contains a hydrothermal cave system of about 50 km, which was formed about 0.5–1 million years ago. This limestone deposit

overlies the Buda Marl and the Tard Clay. After a discontinuity, the next rock is the Hárshegy Sandstone having rough sandy, gravely layers cemented with extraordinarily hard chalcedony. These various deposits underlie the Kiscell Clay, which was mined in the nineteenth to twentieth centuries primarily to produce bricks for the expanding city.

Fifteen million years ago, during the Badenian Age, marine conditions occupied the whole Carpathian Basin. It was during this period that the Rákoss Limestone (on the Pest side) was deposited. In the southern part of Buda, in the region of Budafok-Promontor, the Tinnye Formation was deposited a little later (in the Sarmatian). The present Parliament building was built from this rock. The mining of stone resulted in the construction of 120 km of tunnels, which were subsequently used as wine and champagne cellars. Travertine started to form about 5 million years ago in the Pannonian and continued into the Pleistocene; it can be seen in the Szabadság, Vár, Rózsadomb and Gellért Hill (where loess occurs on the southeast slopes).

## ***Geomorphology***

The city lies at the junction of two major landscapes—the Hungarian Plain and the Hills of Transdanubia. Today's natural landscape emerged at the end of the last glacial period, about 11,000 years ago. Pest, on the left bank of the Danube, is mainly flat, generally 100–150 m a.s.l (metres above sea level) and should be considered a plain although its character is rather that of a half basin; the terrain comprises a series of river terraces that gradually descend towards the Danube. The surface on the Buda side (the right bank) comprises a low mountain range, the Buda Hills, which are 300–500 m a.s.l and separated by valleys. The highest point of the city is the Janos Hill at 529 m a.s.l. The dominance of limestone in the Buda Hills has resulted in the formation of a karstic landscape.

## ***Hydrogeology***

The Danube river is by far the most important watercourse in the city (and Europe), flowing in gentle meanders from north to south. It is 650 m wide in the north, narrowing to 300 m at the foot of the Gellért Hill, where it has long been used as a crossing place. The bed descends at a gradient of 8 cm/km. The velocity and flow vary from 0.5 to 2.0 m/s and 600 to 8000 cumecs (average 2300), respectively. The maximum fluctuation level is about 9 m, but during the spring of 1838, when the ice stopped the flow at Csepel Island, it rose above 10 m devastating most of the inner city of Pest, destroying 2792 houses (50 % of Pest).

About half a million years ago, the river gradually moved east to its present course. Since then and even as recently as a few hundred years ago it formed many channels, for example along the route of what is now the Grand Boulevard. The

present channel is the result of river regulation works, which were carried out at the end of the nineteenth century.

In addition, industrial and municipal wastewater discharges, which vary annually, have influenced the water quality of the river although it has improved in recent years.

The river has two large islands with four smaller ones lying between them. Szentendre Island is 33–34-km long and extends from Visegrád to Budapest. The 58-km-long Csepel Island extends from Budapest to Dunaújváros with the Ráckevei-Soroksári Danube (RSD) flowing parallel to it. New islands and shallow gravel banks were once typical in both the RSD and the main river.

The watercourses on the Pest side are longer, have a larger catchment and a more constant flow than those on the Buda side. The Pest side has mainly groundwater springs (for example Illés Well near the Ludovika Building). Water for the baths is supplied by artificial drilling; the Dagály swimming pool next to the Danube has a well about 100 m deep, the well of the Széchenyi swimming pool is 1000 m deep, whereas the well of the Paskál swimming pool is even deeper, obtaining water from Triassic deposits. The small tributaries (Szilas and Rákos streams) on the Pest side flow in concrete channels.

The Buda side is poor in surface water; the watercourses are short and seasonal, for example the Arany Hill Ditch (which is the northernmost tributary). The Ördög Ditch in the centre of the city is contained in a concrete channel with the last few kilometres being completely culverted (until the recent commissioning of the sewage treatment works at Csepel Island, the watercourse also carried sewage from Inner Buda to the Danube). The city is rich in thermal springs discharging water at 20–40 °C, for example the group of springs at the József Hill, around the Lukács Bath, and the springs at the foot of the Gellért Hill around the Gellért, Rudas and Rác Baths. The latter are mainly supplied from boreholes, which are in a km-long tunnel under the Gellért Hill (the tunnel was drilled between 1970 and 1977). The cold water springs usually discharge higher in the hills, for example Városkút and King Bela's Well. The waters from these karst springs are now partly connected to the city's water supply.

All the still waters are of artificial origin, except temporarily flooded marshland areas. On the Buda side, Feneketlen lake is a flooded, disused clay pit, whereas on the Pest side Naplás lake was formed by the damming of the Szilas stream. The Városliget lake is artificial and has a concrete bed; it functions as a lake for rowing in the summer and as a skating rink in the winter.

## ***Soils (Szabolcs Leél-Össy)***

It is very difficult to find examples of the original, undisturbed soil of Budapest. About 10–20% of the soils of the Pest area are untouched, which is a considerable asset. In the vicinity of Cinkota, there are forests; whereas in the area of the Rákos

**Table 1** Average monthly climate data of Budapest (Light and dark grey cells represent minimum and maximum monthly values, respectively). Light shading=minima; dark shading=maxima

Month:	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Temperature (°C)	0.4	2.3	6.1	12.0	16.6	19.7	21.5	21.1	16.9	11.8	5.4	1.8
Precipitation (mm)	37	29	30	42	62	63	45	49	40	39	53	43
Sunshine duration (h)	62	93	137	117	234	250	271	255	187	141	69	52

stream, there are vast plough lands that stretch to the administrative boundaries of the city. There are nature reserves here, which have remained virtually untouched, for example Merzse marsh—human activity has not changed the original soil conditions on these lands yet.

The upper layer of the regolith was destroyed a long time ago by human activities. However, the Buda Hills are almost undisturbed in spite of the forestry activities. Here the prevailing soil type is the argillaceous brown forest soil formed from the soil on loess (in terrains covered by sandstone, the soil may be podsolized). Agricultural soil types appear in the suburban basins, rendzina soils occur on the karst and alluvial soil in the stream valleys. Red clay occurs in some depressions. In general, it can be said that on the Buda side the rock type immediately below the surface has a decisive effect on the soil types. However, on the Pest side it is not the bedrock but the level of the water table that has the greatest effect on soil formation. In the southern part of Csepel Island and on the southern parts of the Pest side, shifting sand is prevalent. In the depressions, alluvial and meadow soils can be found. Thin veil sand may occur even on the terrace gravels. There was a massive turf formation on marshes and fens.

*Climate (Róbert Mészáros)*

Based on the Köppen and Trewartha global climate classification system, the region of Budapest can be classified as having a ‘warm summer continental climate’ or a ‘continental climate with a long warm season’. However, this description can be refined to focus on regional temperature and precipitation conditions. Accordingly, the climate of the city is mainly ‘moderately warm and dry’, which changes to ‘moderately cool and moderately dry’ with increasing altitude in the region of the Buda Hills. Due to the urban heat island effect, the city centre generally has a ‘warm and dry’ climate. At the same time, the microclimate of the larger city parks is more pleasant and moderate. Based on the long-term observations of the Hungarian Meteorological Service, the average monthly temperature, precipitation and sunshine of Budapest can be seen in Table 1; however, there is considerable annual variation.

During the winter, the coldest part of the city is a relatively small area in the hilly northwest (Buda Hills) with the warmest areas being in the south and east (mainly Pest). A similar situation exists in the summer.

## **Temperature**

The annual mean temperature in the city is about 11 °C. The monthly mean temperature is lowest in January (0.4 °C) and highest in July (21.1 °C). The daily minimum temperature falls below 0 °C, mainly between November and March, but the number of days with frost varies each year. A long-term (even a few weeks) cold period can occur in January and February when a high-pressure area is centred over the whole Carpathian Basin; during this time, the temperature can drop below –15 °C. At the same time, Atlantic depressions and a southerly wind can lead to warm winter weather with temperatures reaching 15 °C. The springs are generally characterized by rapid warming in April with short cold periods with ground frost even in mid-May. Hot periods are frequent in July and August with highs between 32 and 35 °C. During these heat waves, the temperature does not drop below 25 °C, even at night. Autumn temperatures vary over a wide range; in the first part of the season, the weather is generally calm with temperatures reaching 20 °C, even until the end of October. First frosts usually appear in the second week of October followed in November by a rapid temperature reduction. The lowest recorded air temperature was –23.4 °C (11 February 1929); the highest was 40.7 °C (20 July 2007)—an amplitude of 64 °C.

## **Precipitation**

The mean annual precipitation in Budapest is 533 mm, but it increases with height in the Buda Hills. Two wetter (early summer and late autumn) and two drier (midwinter/early spring and early autumn) periods occur during the year. There is considerable variation in precipitation between years, for example 400 mm in dry years such as 2011 and 2012 and almost 1000 mm in wet years such as 2010, more than a twofold increase. The number of days with precipitation is 77 on average.

## **Air Quality**

In the past few decades, as the result of rigid emission reduction strategies in Hungary and the decline of industrial production, the air quality of Budapest has improved. Currently, the most important source of air pollution is traffic; the pollution caused by nitrogen oxides and aerosol particles is significant in some periods. Higher concentrations are generally observed in the winter season, when the concentration of these emissions exceeds the occupational exposure limit for a few days. Emissions from vehicles and residential heating combined with a persistent



high-pressure system over the Carpathian Basin can result in the formation of smog. Higher ozone values, which can be potentially harmful to organisms, can occur during the summer. Detailed data about air quality of the city can be found at <http://www.kvvm.hu/olm/>.

## **Historical Background (Annamária Bárány)**

### ***Pre-Fourteenth Century***

Budapest is built on one of the oldest settlements in Europe; there is evidence of the presence of hominids 420,000–460,000 years ago. Early hominids spread out of Africa and colonized Europe along a small number of routes, including the Danube. It is probable that the Palaeolithic and Neolithic people found the natural resources of the area attractive for the establishment of temporary and then permanent human settlements, particularly the presence of two differing landscapes—the Pest Plain and the Buda Hills, which provided suitable areas for agriculture (including animal husbandry) and viticulture, respectively. The caves provided shelter, whereas the surrounding forests provided opportunities for hunting. The Danube was an excellent source of food (fish and molluscs) and quality water. In addition, the natural features provided good defences; on the other hand, the only relatively easy crossing of the Danube for a long distance up- and downstream was in Budapest. Over the past 7000 years, the area now occupied by the city has experienced many changes in cultures. The first town, which occupied about 30 ha, was built by the Celts in the first century BC. Eventually, the city became part of the Roman Empire and supported a population of about 20,000 people. The Romans were replaced by the Huns and when that empire collapsed, Budapest was occupied by various tribes, including the Avars, who were followed by the Franks. There is no evidence of any significant expansion of the city during the Great Migration Period (c. 400–800).

Between 900 and 904, the centre and the castle of *Kurszán kende* were located in Óbuda (= Old Buda) and in 937 the capital of Hungary was moved to Esztergom and later to Székesfehérvár where it remained for 200 years. The capital city was located in the territories of Pest and Pilis in the thirteenth century by the amalgamation of many small settlements.

As described in the following sections, Budapest was subject to many invasions, which resulted in its destruction and rebuilding many times. In 1241, the city was destroyed by the Mongol invasion and subsequently rebuilt by Béla IV, who also built a castle in the new city of Újbuda (= Buda) in the area of the present Castle Hill. After the end of the Árpád Dynasty, Buda became the seat of Nagy Lajos, the son of Károly Róbert. By this time, it was a busy multinational city with many craftsmen, tradesmen and merchants living and working in it.

## ***Fourteenth to Nineteenth Centuries***

Buda reached its peak in the late fifteenth and early sixteenth centuries when it was part of the Hungarian Kingdom that stretched from the Baltic to the Adriatic Seas. At this time, Budapest had a population of 25,000–30,000 people. The city had an important economic role because of the importance of the crossing of the Danube linking east–west trade.

In 1526, after the battle at Mohács, Szulejmán I destroyed Buda and the castle. In 1541, the Turks invaded Buda and occupied it for almost 150 years. During the Ottoman times, Buda became a remarkable settlement with thriving industry and trade. In 1686, the Habsburgs reoccupied Buda and Pest in a war that resulted in the destruction of the cities and their people. The city was restored by the middle of the eighteenth century and by the end of the century the population started to increase, reaching 35,000–40,000.

The real expansion of Budapest began in the Reform Era (1825–1848), which was an eventful period. The rapid growth attracted many migrants. In March 1838, a large number of buildings were destroyed by a huge flood; many mansions were built in Buda and Pest by wealthy members of the nobility; and in 1848, the Széchenyi Chain-bridge was completed—it became the symbol of the city and the entire era. In the 1870s, a master plan was devised that established a network of roads and boulevards, the height of buildings, areas of green space and other planning issues. The plan was implemented within 20 years. In 1873, Pest, Buda and Óbuda were merged to form Budapest. By the turn of the century, the city had developed into a metropolis with 700,000 residents. It was famous for its sparkling cultural life, coffee shops, thermal baths and nightclubs. During this period, it was reported to be the second largest milling centre in the world. The railway network was constructed between the early- and mid-nineteenth century, converging at the riverside quays. Trams appeared in 1887 and the first underground railway in Europe was opened in 1896.

## ***Twentieth and Twenty-First Centuries***

Electric lighting was provided between 1909 and 1910, by which time the population size had reached 1 million. Although 1918 saw the break-up of the Austro-Hungarian Empire, the population of Budapest continued to grow slowly. By the 1930s, it had started to recover when it was again affected by the 1939–1945 War. In 1944, the military front line reached Budapest resulting in all of the bridges, Buda Castle and most of the dwelling and public buildings being destroyed. Tragedy struck again in 1956, the year of the Hungarian Revolution, and the subsequent Russian invasion resulted in conflict and destruction. The reconstruction of the damage caused during these periods was completed by the end of the 1960s. The east–west line of the metro was opened in 1970 and the north–south line 6 years later. The end of the ‘Communist Period’ in 1990 was followed by large-scale development. The

buildings, which were financed by private investment, have changed the cityscape significantly. In addition, the housing, retail and other developments started to expand into the Buda Hills. Western investment, since 1990, has paid little respect to and had little consideration for the quality of the natural environment in the city and its expansion.

## **Vegetation and Major Habitat Types (Zoltán Tóth and Zoltán Bajor)**

### ***Forests***

Pollen analyses have shown that 4000–5000 years ago, the deciduous forest above 400 m a.s.l. was dominated by *Fagus sylvatica* (Beech), which later became mixed with *Carpinus betulus* (Hornbeam). In this period, the flora and fauna was mainly unaffected by human activity; subsequently, the natural environment was changed by successive human activities and values (Borbás 1879, Péntzes 1942). However, *F. sylvatica* has remained dominant on the northern slopes and in the deep gorges of the Buda Hills, where it descends to 250 m a.s.l. As the city expanded into Buda, small populations of *Fagus* have survived in isolated gardens, in the valleys and on northern slopes. These days, the species exists only on the ridge of the Normafa and János Hills where beech forests (natural and of mixed age) can be found in their greatest expanse. Smaller areas of beech forest occur in the Kakukk and Frank Hills in the south, whereas to the north of the János Hill beech forests only occur on parts of the Great Hárs Hill and the protected slopes of the Hármashatár Hill. Because the species has no forestry value, virtually all of its original distribution has been lost and it is unlikely to expand in the future. Beech forests have a dense canopy; consequently, the field layer is sparse but several protected species do occur, for example *Lilium martagon* (Turk's-cap Lily), *Aconitum vulparia* (Wolfsbane) and orchids such as *Neottia nidus-avis* (Bird's-nest Orchid).

Species of *Quercus* (Oak) are characteristically found on the southern slopes of the Buda Hills. Seminal *Quercus petraea* (Sessile Oak) forests are widespread up to 250–300 m a.s.l. on the János Hill and on Great Hárs and Hármashatár Hills. *Q. cerris* (Turkey Oak) is another typical oak species in the Buda Hills; for example the Kamaraerdő forest, which occupies 81 ha, comprises mainly *Q. cerris*. Karst shrub forests of *Q. pubescens* (Pubescent Oak) and *Fraxinus ornus* (Manna Ash) occur on exposed areas of limestone and dolomite stretches, for example Sas, Rupp, Kálvária, Szarvas and Csúcs Hills and on the Devil's Rock in District II. The rather dense canopy of oak forests hold fewer plant species compared to the open foliage of the Turkey Oak forests and karst shrub, which contain several rare protected plant species such as *Ophrys scolopax* (Woodcock Bee-orchid), *Limodorum abortivum* (Violet Limodore), *Cephalanthera rubra* (Red Helleborine), *C. damasonium* (White Helleborine) and *Orchis purpurea* (Lady Orchid).

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