Geology

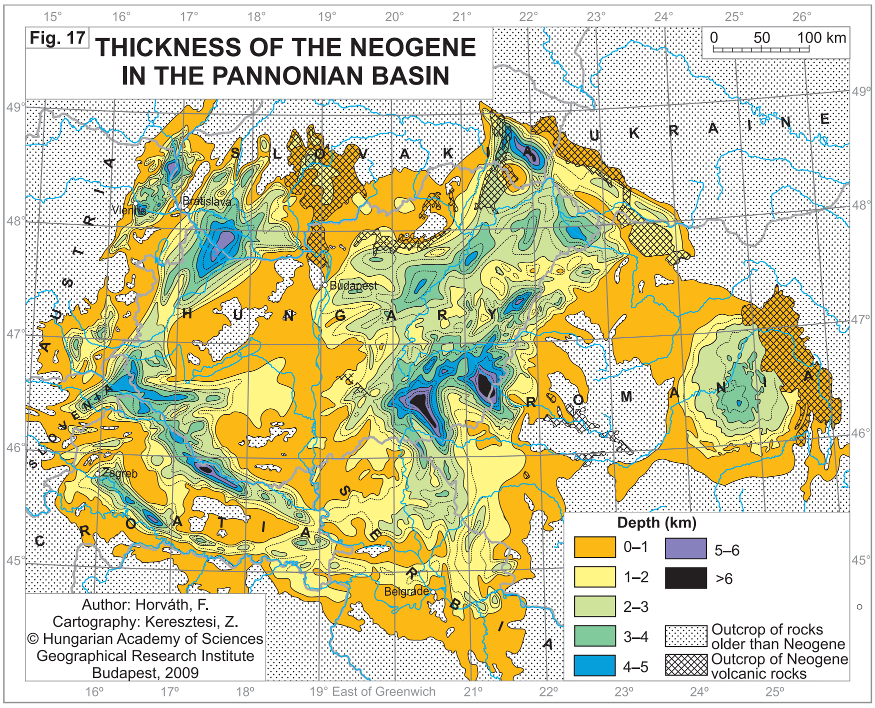
The pre-Tertiary geologic structure of the Pannonian (Carpathian) Basin exhibits a variety of effects ranging from rifting to collisional mountain building in several stages, reflecting the motions of the European and African Plates from the Palaeozoic to the Tertiary. Tertiary events led to the formation of a young basin system through crustal thinning beneath the area. The present day geologic features of Hungary, as well as those of the whole Pannonian region are determined mainly by its Late Tertiary evolution, featuring large basins over anomalously thin crust (22–32 km), a high geothermal gradient (41–56°C/km) and high surface heat flow (80–120 mW/m^2). A series of one to eight kilometre thick lacustrine, deltaic and fluviatile sediments from the Late Miocene–Pliocene Pannonian Lake filled up the large basins, now overlain by Quaternary loess, windblown sand and alluvial deposits, usually covering the surface of the plains beneath the soil (*Figure 17*).

The Pannonian Basin system actually consists of several basins, separated by ranges (inselbergs) made up of predominantly Palaeozoic, Mesozoic and Palaeogene sedimentary sequences and Tertiary igneous rocks (*Figure 18*).

Metamorphosed Palaeozoic and Mesozoic complex outcrops are found in the north-western part of Hungary, in the Sopron and Kőszeg Mountains near the Austrian border, representing the continuation of the Austroalpine ranges.

The Transdanubian Mountains, extending for 250 km in a direction of north-east to south-west, consist of hills and mountains with a great variety of geologic buildup. Lower Palaeozoic phyllite, Permian fluvial sandstones and Triassic shales and carbonates are known to exist north of Lake Balaton (the Balaton Upland), while Carboniferous granite constitutes a large part of the Velence Hills, located north-east of Lake Balaton. Other parts of the Transdanubian Mountains (Keszthely, Bakony, Vértes, Gerecse, Pilis and Buda Mountains) are mainly made up of Triassic carbonates, however, Jurassic, Cretaceous and Eocene formations also occur in the central zone of the synform, determining the basic structural pattern of these mountains.

The North Hungarian Mountains possess a very complicated geologic setting. In the north-eastern part of the region, in the Szendrő and Uppony Hills, there are outcrops of slightly metamorphosed Palaeozoic shale and carbonates. The Bükk Mountains are made up of slightly metamorphosed Upper Palaeozoic–Jurassic series and a similarly metamorphosed Jurassic sedimentary and magmatic complex, which was overthrust onto the former series. Both complexes are covered by shallow marine Eocene sedimentary rocks. Nappes of Triassic carbonates make up the Aggtelek Mountains near the Slovakian border. Other parts of the North Hungarian Mountains are mainly composed of Paleogene and Neogene siliciclastic sequences



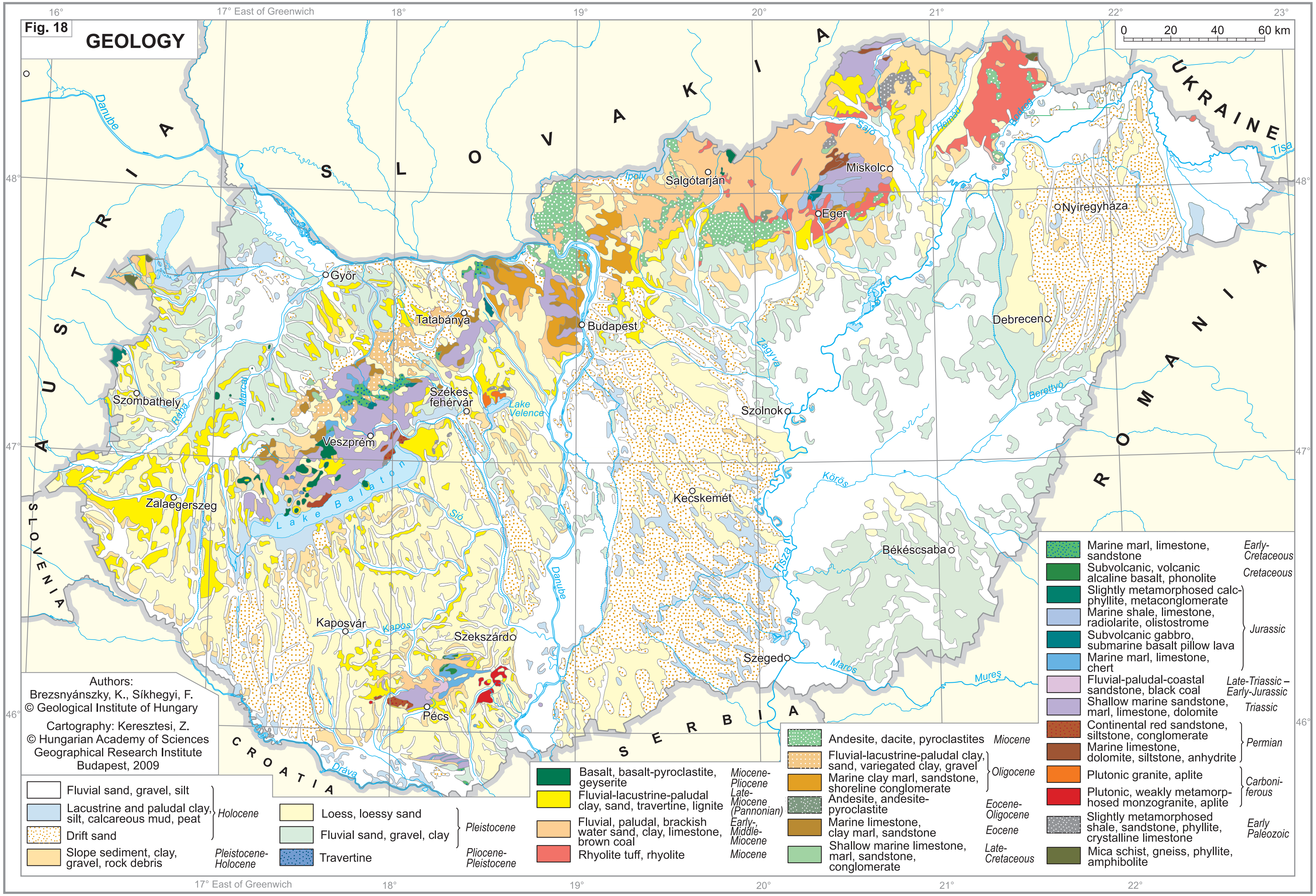


Fig. 18
GEOLOGY
0 20 40 60 km
UKRAINE
SLOVAKIA
ROMANIA
SERBIA
CROATIA
SLOVENIA
AUSTRIA
Győr
Tatabánya
Budapest
Salgótarján
Miskolc
Eger
Nyíregyháza
Debrecen
Szolnok
Kecskemét
Békéscsaba
Szeged
Székes-fehérvár
Veszprém
Szombathely
Zalaegerszeg
Kaposvár
Szekszárd
Pécs
Danube
Tisza
Lake Balaton
Lake Velence
Authors:
Brezsnyánszky, K., Síkhegyi, F.
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Cartography: Keresztesi, Z.
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Budapest, 2009
Fluvial sand, gravel, silt
Lacustrine and paludal clay, silt, calcareous mud, peat
Holocene
Drift sand
Slope sediment, clay, gravel, rock debris
Pleistocene-Holocene
Loess, loessy sand
Fluvial sand, gravel, clay
Pleistocene
Travertine
Pliocene-Pleistocene
Basalt, basalt-pyroclastite, geyserite
Miocene-Pliocene
Fluvial-lacustrine-paludal clay, sand, travertine, lignite
Late-Miocene (Pannonian)
Fluvial, paludal, brackish water sand, clay, limestone, brown coal
Early-Middle-Miocene
Rhyolite tuff, rhyolite
Miocene
Andesite, dacite, pyroclastites
Miocene
Fluvial-lacustrine-paludal clay, sand, variegated clay, gravel
Marine clay marl, sandstone, shoreline conglomerate
Oligocene
Andesite, andesite-pyroclastite
Eocene-Oligocene
Marine limestone, clay marl, sandstone
Eocene
Shallow marine limestone, marl, sandstone, conglomerate
Late-Cretaceous
Marine marl, limestone, sandstone
Early-Cretaceous
Subvolcanic, volcanic alcaline basalt, phonolite
Cretaceous
Slightly metamorphosed calc-phyllite, metaconglomerate
Marine shale, limestone, radiolarite, olistostrome
Subvolcanic gabbro, submarine basalt pillow lava
Marine marl, limestone, chert
Jurassic
Fluvial-paludal-coastal sandstone, black coal
Late-Triassic – Early-Jurassic
Shallow marine sandstone, marl, limestone, dolomite
Triassic
Continental red sandstone, siltstone, conglomerate
Marine limestone, dolomite, siltstone, anhydrite
Permian
Plutonic granite, aplite
Plutonic, weakly metamorphosed monzogranite, aplite
Carboniferous
Slightly metamorphosed shale, sandstone, phyllite, crystalline limestone
Mica schist, gneiss, phyllite, amphibolite
Early Paleozoic

and Oligocene (in the eastern Mátra Mountains), and Miocene igneous rocks (Börzsöny, Cserhát, Mátra and Tokaj Mountains).

Carboniferous granites are exposed in the south-eastern part of the Mecsek Mountains in South Transdanubia. Thick Permian to Lower Triassic continental red beds and Middle Triassic carbonate sequences make up the anticline of the western Mecsek Mountains, whereas extremely thick, marine, siliciclastic Jurassic sediments and Cretaceous magmatic complexes constitute the syncline of the eastern Mecsek Mountains. Located south of the Mecsek and Villány Mountains have an imbricated structure consisting of Mesozoic carbonates.

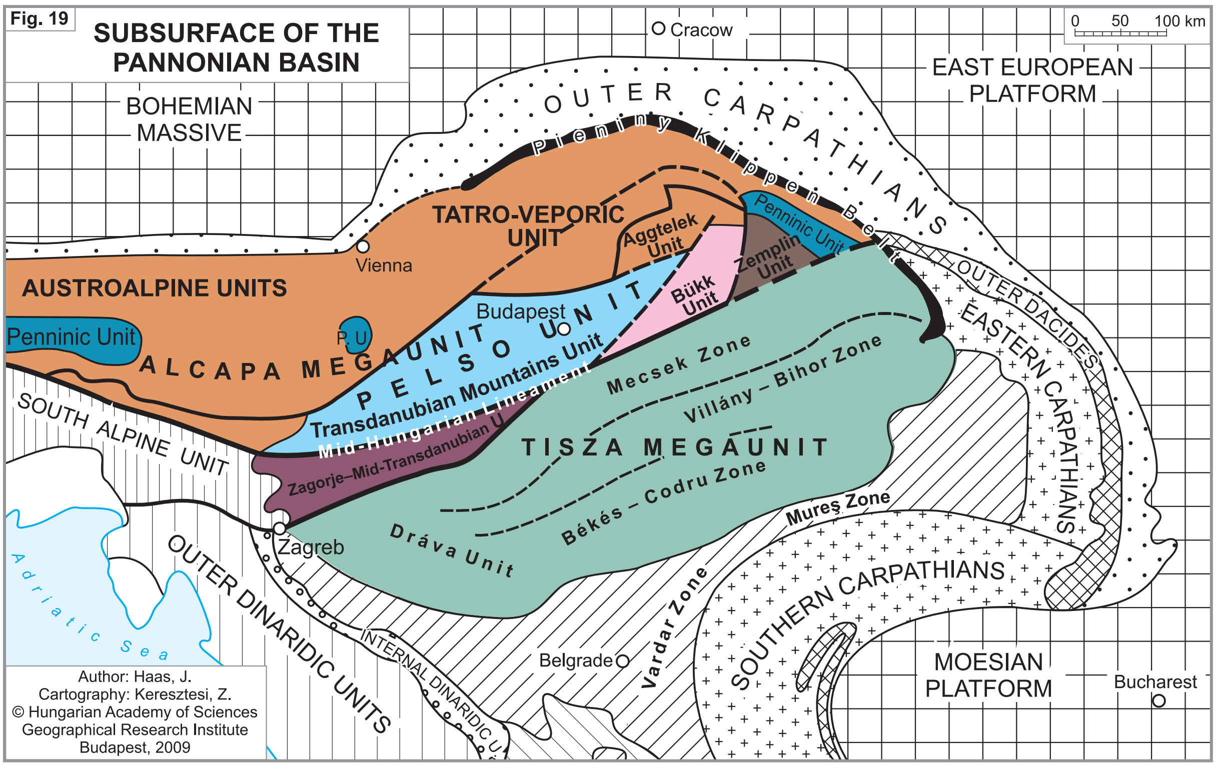
Geophysical measurements and drilling activities carried out over the last couple of decades have revealed that beneath an ordinarily relatively thick and uniform Late Tertiary cover, the basement of the Pannonian Basin is rather complicated. It exhibits a mosaic pattern made up of heterogeneous structural elements; a collage of allochthonous terranes derived from different parts of the Tethyan realm. Moreover, these elements (structural units or terranes) were arranged in different ways during the course of the long evolutionary history of the Pannonian region. The present-day locations of these structural units are presented in *Figure 19*.

The pre-Neogene basement of the Pannonian Basin is divided into two large units by the Mid-Hungarian Lineament trending east-northeast to west-southwest. These megaunits of markedly different geologic history, namely the Tisza Megaunit (or Tisia Terrane) and ALCAPA Megaunit, were juxtaposed only during the latter stage of the pre-Neogene restructuring of the Pannonian realm in the Late Oligocene–Early Miocene (18–25 million years ago).

The Tisza Megaunit consists of blocks accreted during the Late Paleozoic Variscan orogenic phases, when it formed a part of the European Variscan Belt. It separated from this belt in the Middle Jurassic and since the late Early Cretaceous it has moved as a separate entity, i.e. a microcontinent.

The ALCAPA Megaunit is a composite terrane consisting of metamorphosed remnants of the Ligurian-Penninic Ocean (Penninic Unit) that are overthrust by elements of the European plate margin and the Adriatic microplate (Austroalpine-Tatro-Veporic Unit), respectively. The Pelso Unit is found south of this unit. It is also a composite terrane that is made up of the Transdanubian Mountains Unit, along with the Zagorje-Mid-Transdanubian, the Bükk and the Aggtelek Units. Prior to the large scale displacements, the Transdanubian Mountains Unit was

Fig. 19 SUBSURFACE OF THE PANNONIAN BASIN



located between the South Alpine and Upper Austroalpine Units. All of these units belonged to the margin of the Neotethys Ocean. In the Zagorje-Mid-Transdanubian Unit, strongly sheared, displaced elements of the South Alpine and Internal Dinaridic Units occur. The Bükk Unit, that also contains small fragments of the oceanic basement of the Neotethys, is derived from the Dinaridic realm, together with metamorphosed formations of the Aggtelek Unit that are overthrust by nappes of the Tatro-Veporic Unit.

The main stages of structural evolution were as follows:

– The *Pre-Alpine phase*, which fits into the Palaeozoic evolutionary history of Europe. Features of the multiphase metamorphic complexes and granitic rocks point to a Central European Variscan (Moldanubian Zone) affinity of the basement of the Tisza Megaunit, whereas the lack of higher-grade metamorphism suggests a South Alpine-Dinaridic affinity of the elements of the Pelso Unit.

– The *early period of the Alpine evolutionary cycle*, prior to the main orogenic phases, that lasted from the Late Palaeozoic to the Middle Jurassic. In this period structural evolution was mainly governed by the heterochronous opening of the ocean branches, i.e. the Neotethys and the Ligurian-Penninic branch of the Atlantic Ocean, leading to a disintegration in the margins of the surrounding continental plates and a separation of microcontinents and plate fragments that would play a significant role in the further development of the region.

– The *later period of Alpine structural evolution*, lasting from the Middle Jurassic to the Early Neogene. This period witnessed a closure of the Neotethys in the Middle to Late Jurassic and the Ligurian-Penninic ocean branch during the Cretaceous to Early Tertiary. As a result of this, this interval was characterised by intensive tectonic deformations, displacements, and re-arrangements of the structural units (terranes). The terranes forming the basement of the Pannonian Basin were to be found in their present day, juxtaposed setting by the end of this stage.

– The phase that formed the Pannonian Basin was initiated by attenuation of the crust, leading to intense volcanism and significant but uneven subsidence during the Miocene. An andesite-dacite stratovolcanic chain, subparallel to the Carpathian arc was formed 16 to 13 million years ago. As a result of the unequal subsidence pattern, sub-basins filled with several kilometres thick sediment developed, which were separated by islands and ranges. About 12 million years ago, in the Late Miocene (Pannonian) subsidence of the articulated basement of the basin system continued and accelerated. Coevally, due to uplift of the Carpathian arc the connection with the Black Sea had ceased to exist and a large lake came into being, the Pannonian Lake. Parallel to the intense subsidence, basalt volcanism started in some parts of the Pannonian Basin (e.g. the Bakony-Balaton Upland and Kemenesalja) about 7.5 million years ago. Sediments derived from the uplifting Alps and Carpathians gradually filled up the lake, step-by-step through advancing deltas. By the Pliocene, in place of the former lake a fluvial-lacustrine system had established with large swamps and wetlands. 2.5 million years ago an intense uplift of Transdanubia, the western part of the Danube-Tisza Interfluve, and of the present day mountains began, whereas the subsidence of the deep basins continued, giving rise to the deposition of thick fluvial sediments during the Pleistocene. Loess is a characteristic sediment, widely found in hilly regions, on piedmonts and fluvial terraces. The thickness of the loess sequences locally reaches 100 m along the Danube.