GEOPHYSICS

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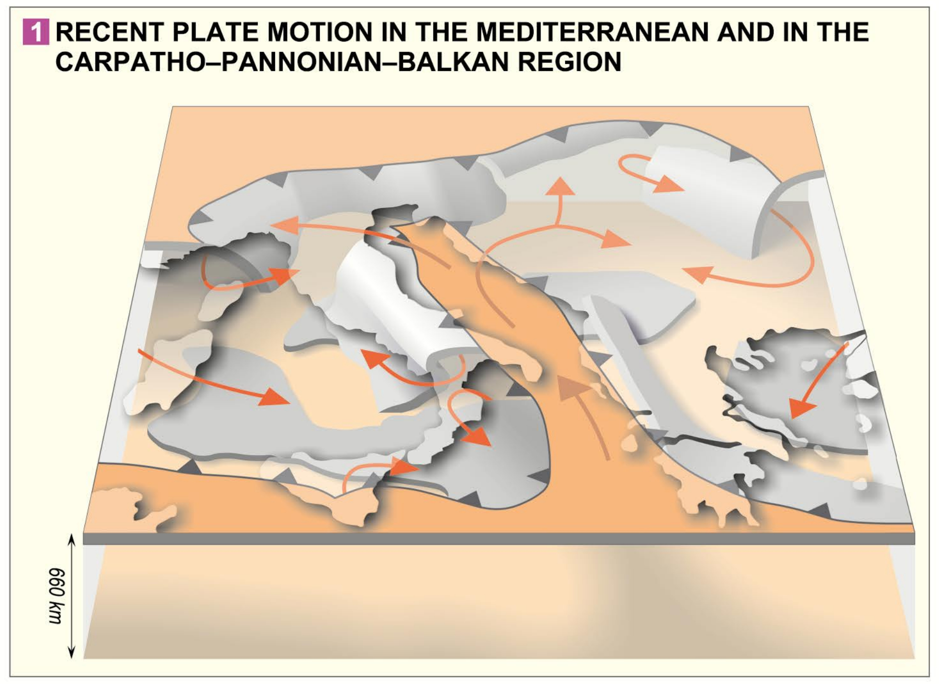
The Carpatho–Pannonian Area and the plate tectonics

In modern geophysics, movements of the lithosphere are described by the concept of plate tectonics. The surface of the Earth is the top of lithospheric plates. Their thickness varies from some tens of kilometres to up to 250–270 kilometres. These plates provide the upper layer of our planet, covering the surface like a completed jigsaw puzzle. Beneath it we find the asthenosphere, a layer showing liquid-like characteristics. The lithospheric plates float on top of it with some lateral movements. The mantle of the Earth consists of the lower lithosphere, the asthenosphere and the lower mantle, and its cumulative thickness is almost 2,900 kilometres. Beneath the mantle there is the metallic core of the Earth. The slow convective currents of the mantle, especially of the asthenosphere, keep the lithospheric plates in movement, while the origin of these currents is the heat rising from the centre of the Earth. The deeper, warmer parts of the mantle emerge very slowly, while the colder upper parts seek a way downward. As a combination of these movements, convective cells form in the mantle, which is the main mechanism of the heat transfer there. The lithospheric plates are divided into plates with oceanic and with continental crust. The oceanic ones are thinner. They are produced by the divergent plate boundaries along mid-oceanic ridges. These linear features follow the upper leg of the upstream of the asthenospheric material. Where plates collide at convergent plate boundaries, the one with the higher density (in case of ocean–continent collisions, this is always the oceanic one) is subducted. Its material, in some cases, can reach even the core–mantle boundary, travelling with the downward side of the convective cell. The collision of two continental plates produces large and high mountain ranges.

The formation and progress of the Carpatho–Pannonian Area is a consequence of the collision of two such lithospheric blocks: the African and the Eurasian plates. Geodynamic forces move them in the direction of each other. In regional geodynamics, the Adriatic region is a part of the African plate and move with it. The result of the continental collision is the mountain ranges of the Alps and the Dinarides. The plate and microplate structure of the region is quite complex as a result of the tens of millions of years that this collision process has been occurring. These microplates can be identified by geological features on the surface and by geophysical methods in the depth 1.

Formation of the Pannonian Basin, situated between the Alps, the Carpathians and the Dinarides, started in the Miocene, about 15 Mya, as a result of the African–Eurasian plate collision. At that time in the present location of the basin there was a smaller sea, the Magura Ocean. The collision of the African and the Eurasian plates pushed the ranges of the Alps very high; the over-elevated material tried to escape laterally. The only real way to escape was to the east-northeast, to the Magura Ocean, as the original push came from the south, while the western and northern directions were closed by consolidated structural units. The front of this eastward extension formed the ring of the Carpathians. The oceanic plate of the Magura subducted and this subduction resulted in the chain of volcanic ranges within the Carpathians from near Budapest to the Harghita (Hargita) Mountains in Transylvania (Romania). The Magura plate cannot be found at the surface anymore. Its remnants are at a depth of some hundreds of kilometres, causing increased seismicity of the Vrancea zone in central Romania as well as post-volcanic events in East Transylvania.

The extending Pannonian Basin finally collided with the Ukrainian Shield at the eastern end of the former Magura. Thus the extensional basin came under geodynamical pressure, which is characteristic of it even nowadays. The region is compressed along a SWW–NEE axis and the eastern and western parts are very slowly approaching each other. The engine of this ongoing movement is still the collision of the African and Eurasian plates, driven by the processes in the mantle.



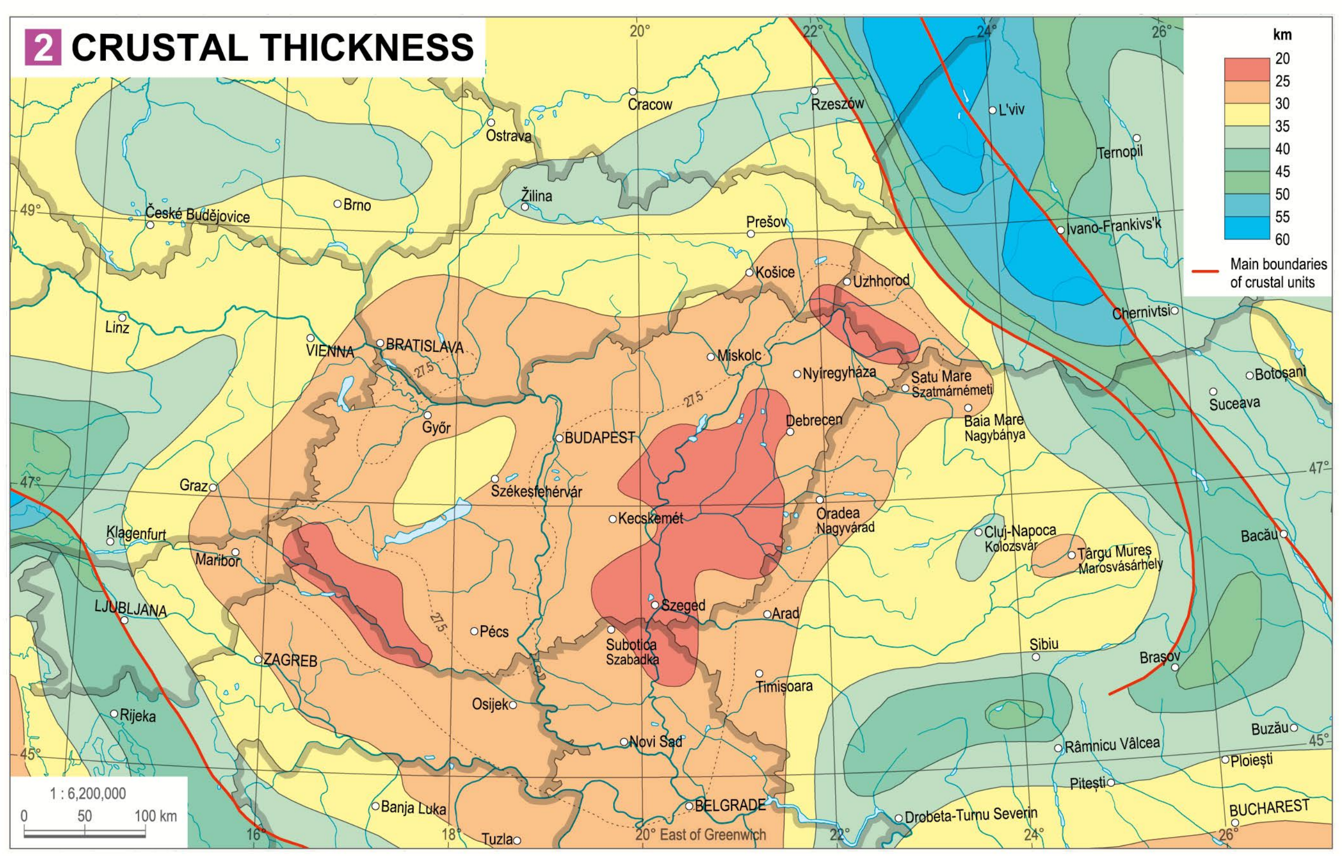
1 RECENT PLATE MOTION IN THE MEDITERRANEAN AND IN THE CARPATHO–PANNONIAN–BALKAN REGION

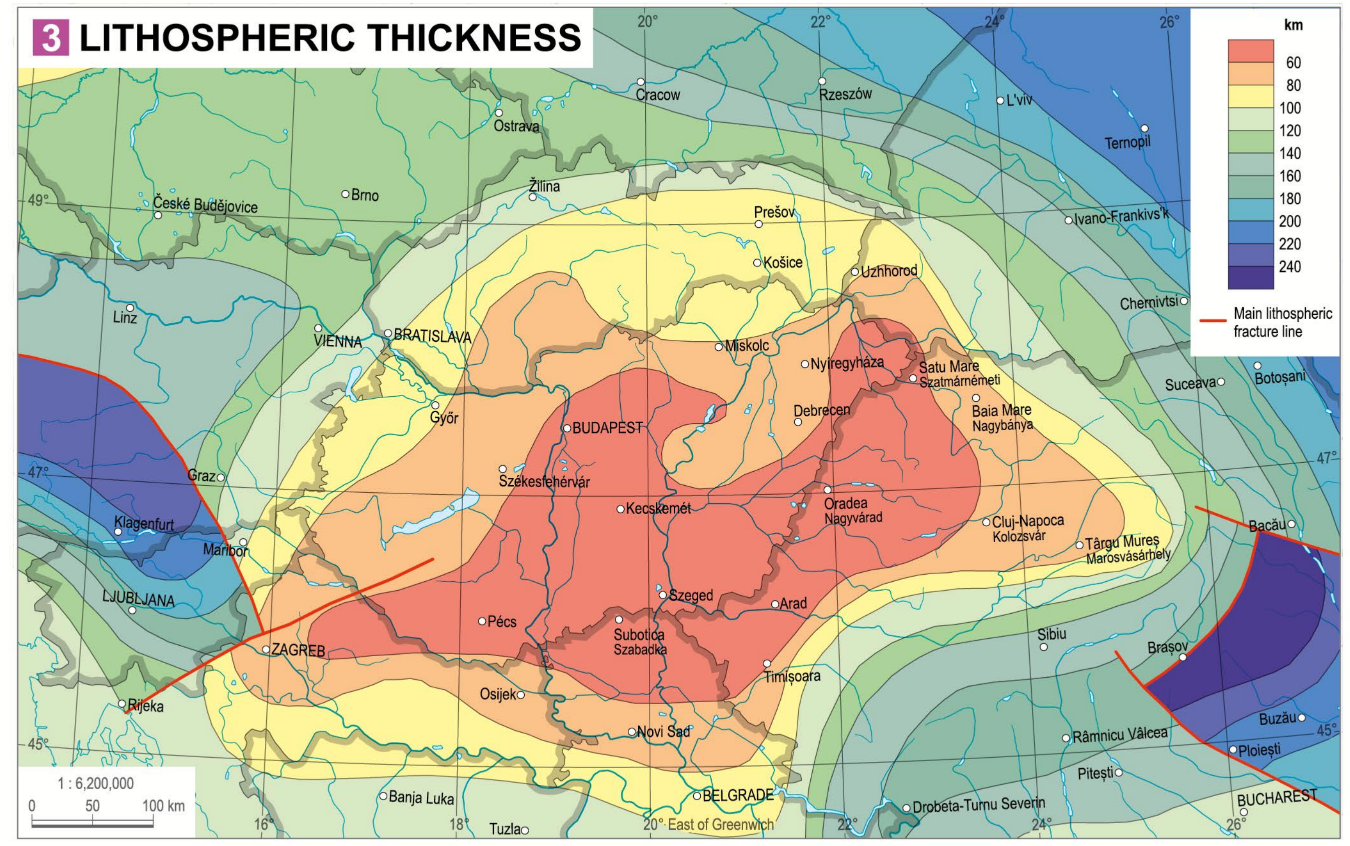
Crustal and lithospheric thickness

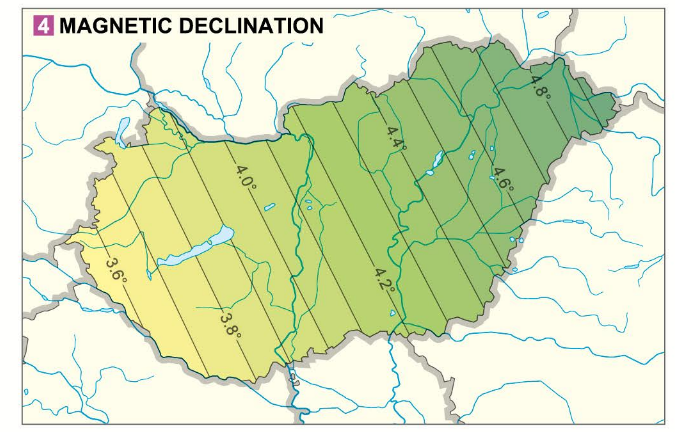
The lithosphere, consisting of solid rocks, can be divided into two parts by its chemical composition. The upper part is the crust of the Earth. The lower one is the mantle-lithosphere, which is still solid, but chemically similar to the mantle.

In the central parts of the Pannonian Basin, the thickness of both the lithosphere and the crust is below the continental average. This is the result of the basin formation and of the subsequent geodynamical processes. In the middle of the basin – apart from the Transdanubian Range – the crustal thickness is less than 30 km 2; thickness of 60 km or more can be found only along the Alpian axis and in the collision zone of the Carpathians and the Ukrainian Shield. According to geodynamics, in the mountain ranges the crustal thickness is greater; however, this is not consistent throughout the region. Under the ranges of the Alps, the Dinarides and the Carpathians the crustal thickness is usually greater compared to the neighbouring flatlands and hilly areas. However, in the highest part of the Carpathians, in the High Tatras region the thickness is slightly less than in other parts of this mountain range.

The thickness pattern of the lithosphere, consisting not only of the crust but also the upper, solid part of the mantle, is a bit simpler. The central region of the basin is characterised by a lithospheric thickness of around 60 km 3. The lithosphere is thicker towards both the Alps and the Carpathians, while in the central Alps and in the Ukrainian Shield it is over 200 km thick. In the Pannonian region, the highest observed lithospheric thickness occurs in the southern end of the Eastern Carpathians, in the Vrancea (Háromszék) Mountains. This is the result of a specific situation: this is the place where the subducted plate of the former Magura Ocean – which is somewhat detached from the present, active lithosphere – is sinking into the mantle of higher viscosity. According to the depth of Vrancea earthquakes, as well as to the anomalies of propagation velocity of the earthquake waves, the bottom of this detached lithospheric slab can be estimated at a depth of almost 300 km.

2 CRUSTAL THICKNESS


3 LITHOSPHERIC THICKNESS


4 MAGNETIC DECLINATION


Geomagnetism

The magnetic field of the Earth has two basic origins. One is connected to the outer core, a mostly liquid sphere with high iron density. Cylindrical currents occur here because of the axial rotation of the Earth. As the charged particles make circle-like motions, this so-called geomagnetic dynamo results in a magnetic field. The major portion of the magnetic field of the Earth is based on this. The direction and the magnitude of the mentioned cylindrical currents vary continuously and in non-predictable ways. When the majority of these cylinders start to show a different direction of rotation than before, that means that the polarity of the magnetic field is changing; the magnetic polar switch occurs. The other source of the total magnetic field of the Earth is the upper atmosphere. Electrically charged particles from the Sun and from outer space interact with the inner magnetic field. The result is the magnetosphere around the Earth and its field, the external magnetic field. Its magnitude changes rapidly, compared to the inner field, because of the variation in the flux of the charged particles. As the main trigger of the external field is the Sun, the strength of this field shows a characteristic daily pattern.

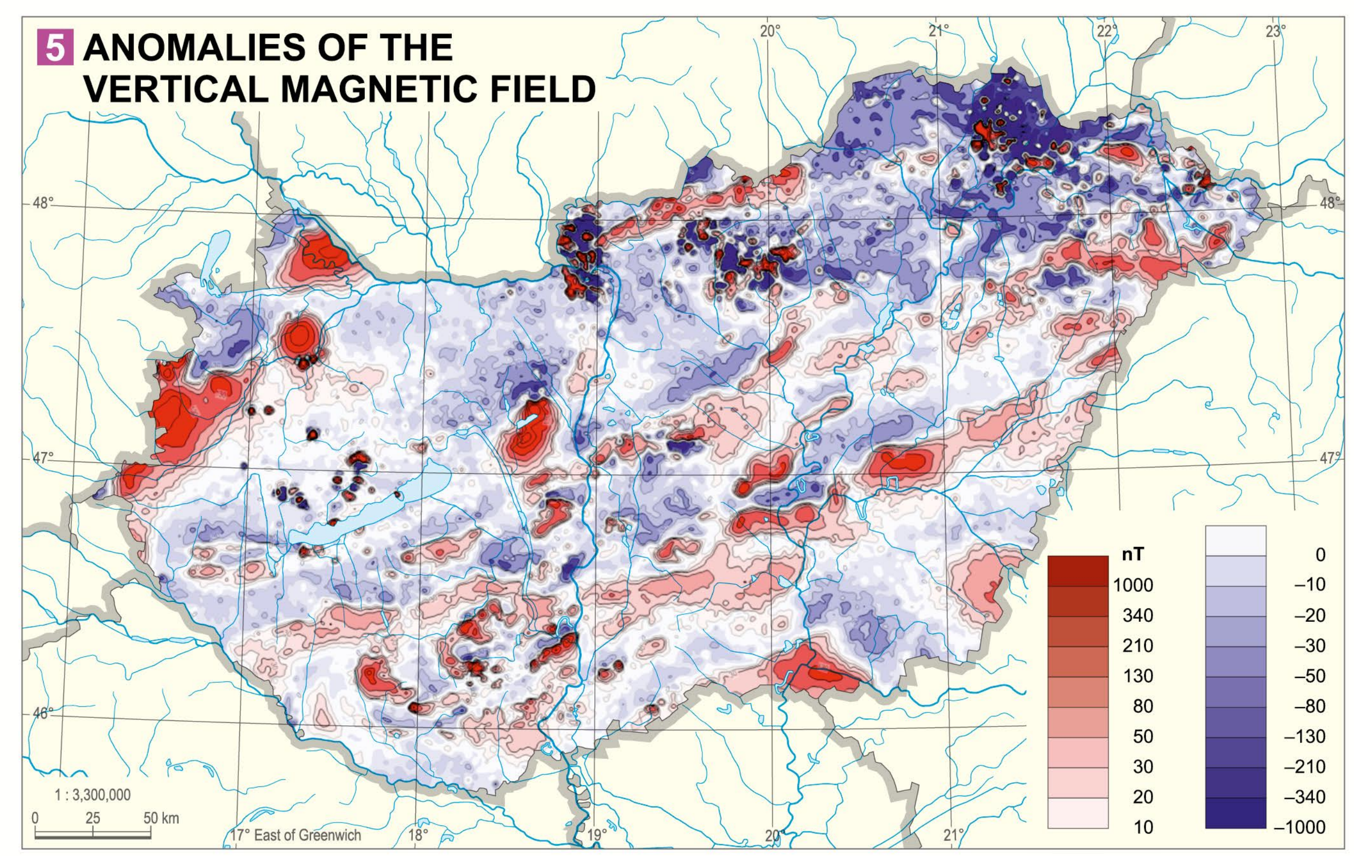
The magnetic field of the Earth is similar to the field that would be produced by a magnetic dipole location somewhere near to the centre of the planet, although its pattern is a bit more complex. The geomagnetic poles, where the local magnetic field vector is vertical, are in different places than the geographic poles. This is the result of the non-parallel orientation of the cylindrical currents. Thus the magnetic north showed by a compass is usually different from the true (or astronomic or geographic) north. The angle difference between the magnetic and true north is called magnetic declination. Its value in the Pannonian region is a few degrees, and its change – even annual change – can be observed by precise measurements 4.

However, the observed magnetic field is affected by other factors, too. There are characteristic magnetic sources such as some kinds of geological or – on a smaller scale – some artificial (e.g. archaeological) structures, whose effect can be distinguished from the background noise. The magnetism of geological sources is provided primarily by its iron content. Thus magnetic exploration in geophysics is mainly aimed at iron-containing rocks, usually volcanic, typically basaltic bodies and some metamorphic rocks of volcanic origin. The magnetic effect of the source quickly decreases with distance. Therefore, the details of near-surface sources can be studied, while in the case of deeper sources – at several hundred metres or a few kilometres depth – only their general characteristics (mass, extent) can be estimated. The magnetic field is observed and mapped in nanotesla (nT) units.

The big magnetic anomalies in present-day Hungary are connected to volcanic bodies (at the surface or buried) and to metamorphic rocks transformed from volcanic rocks. The latter type is more characteristic in the Alpokalja (Eastern Alpine Foreland) region, in the Kisalföld (Little Hungarian Plain) and in some strips of the Alföld (Great Hungarian Plain) 5. In the volcanic part of the North Hungarian Range a chaotic mix of strong positive and negative anomalies is detected. Meanwhile, the anomalies of the buried bodies show uniform, positive anomaly patterns. The cause of this difference is that surface erosion exposes similar volcanic rocks of different cooling times. Different time also means different geomagnetic polarity, and being at the surface, near to our observations, their positive and negative anomalies are strong. On the contrary, in the case of buried bodies, the distance between the magnetic source and the observation is wider; the magnetic anomalies show the cumulative effect, which is a much simpler pattern.

Heat flow

Towards the internal part of our planet the temperature rises; it can be as high as 5,000 °C in the core. The heat flows to the cooler surface. The cumulative surface heat power is approximately 46 TW, of which 20% is estimated to come from the cooling of the core, while 40% is from the cooling of the mantle. Radioactive decomposition probably accounts for the remainder, with an estimated 15% occurring in the continental crust and 25% in the mantle. The heat from the core warms up the lower parts of the mantle, which slightly expand in volume, meaning that their density decreases, thus they start to rise towards the surface. Upon reaching the upper, cooler part of the mantle, they have to move laterally; as they are cooling, their density rises again. With the subducting oceanic plates they sink back to the core–mantle boundary, where they are warmed up again, and this cycle of thermal convection starts again. This process is made a bit more complex as the mantle is not only heated from below by the core but also from inside by radioactive decomposition. The heat propagates in the solid lithosphere by conduction. In thinner lithosphere areas, where the hot mantle material is closer to the surface – as at oceanic plates – more heat reaches the surface. On the contrary, in the case of thicker plates, e.g. continental plates, heat flow is lower in the surface. Volcanic fields are exceptional: along the ruptures – even temporary ones – directly connecting the mantle and the surface the stream of the glowing magma brings a great deal of heat to the surface, either temporarily or constantly.

5 ANOMALIES OF THE VERTICAL MAGNETIC FIELD


The most important characteristics of the heat reaching the surface is the heat flow (or in more precise terms, the heat flow density), which means the thermal power crossing a surface unit, expressed in W/m^2. The average heat flow value at the surface of the Earth is 90 mW/m^2, varying in the range of 30–180 mW/m^2. Even higher values can be observed in volcanic fields and mid-oceanic ridges, where the hot asthenospheric material directly reaches the ocean floor. In the thin oceanic plates the average heat flow is around 100 mW/m^2, while at the surface of the thicker continents it is only 65 mW/m^2. The heat flow characterises the geothermal potential of a region.

The central and southern parts of the Pannonian Basin and some regions of the Alps are characterised by high heat flow values – in some places significantly higher than the continental average 6. The maximum occurs around Belgrade and in some deep sub-basins of the Alföld (e.g. the Lower Tisza Plain, Jászság and Békés–Csanád regions).

The lowest regional heat flow values occur primarily in karstic areas: in the Dinarides (especially the Karst/Kras Plateau itself), in the central part of the basin of the Transdanubian Range, the Bükk Mts. and the area of the Slovak and Aggtelek Karst. This is a result of the cooling effect of the cold-water inflow on the limestone bodies in the karstic plateau zones. This once cold water is gradually heated. Therefore, at the flanks of the karstic mountain it usually reaches the surface again as warmer, sometimes thermal water (e.g. Lake Hévíz, Budapest thermal springs).

An interesting and exceptional high heat flow anomaly occurs at Mt. Ciomatul Mare (Nagy-Csomád) in eastern Transylvania. According to the latest research, this volcano cannot be considered as fully extinct; the last eruption was only 20,000–30,000 years ago. The high heat flow value supports this interpretation and it also explains the majority of the sub-volcanic events in the area.

The temperature of rock bodies has an important influence on their geophysical characteristics: in cooler, rigid rocks the tension is more probably released by sudden displacements, causing stronger earthquakes. In a warmer rock environment the tension tends to cause continuous deformation; the result is lower magnitude earthquakes. From this point of view, the higher heat flow in the zone of the western Pannonian Basin and the northern Alps is important; even the obvious tension producing the peaks of the Alps is followed by fewer and smaller earthquakes. The high heat flow of the Ciomatul Mare (Nagy-Csomád) region, however, does not rule out earthquakes in the Eastern Carpathians: the tremors here come from much deeper, from the detached lithospheric slab.

Boiling geothermics

The heat flow from the depths of the Earth can provide us with geothermal energy. Higher heat flow usually means higher geothermal gradient, thus temperature rises quickly with depth. This means the temperature of the rocks; however, if there is water in the ruptures of the rock body, it will also be heated to this temperature, given enough time. Thus, this water is heated to become thermal water. The most common way of geothermal energy production is thermal water mining. Where we see higher heat flow values in the map 6 (e.g. in the southern part of the Alföld), usually the temperature of the water at depth is higher. Thus, usage of geothermal energy for municipal heating systems and agricultural purposes is more intensive there. Also, the warmest thermal baths are also in the higher heat-flow-value areas.

Earthquakes

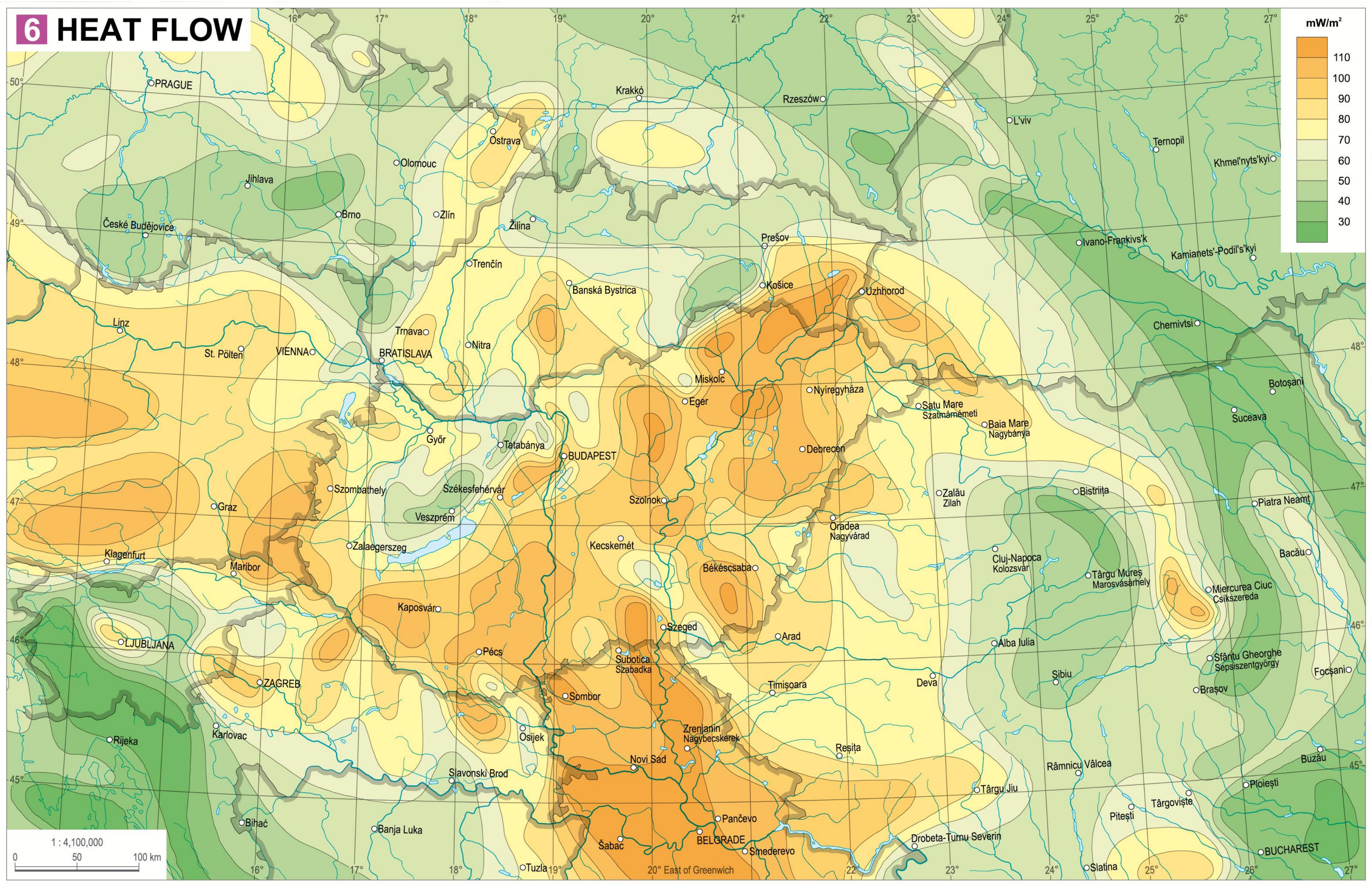
Earthquakes are perhaps the best known phenomenon related to geophysics. In the Earth's crust, or more precisely in the lithosphere, continual tectonic movement is taking place. Lithospheric plates collide with each other, move side by side, or are pushed under one another (subduction). During these tectonic movements, huge mechanical stresses accumulate in the solid rocks, sometimes leading to the breaking of rocks, which produces faults in the geological environment. This break always occurs where the rock plate is the weakest. Some faults are active at present, the stress accumulation is still taking place, and one side of the fault is moving relative to the other. For inactive fault lines, this process stopped at some time in the past; they just bear geological witness to older tectonic movements.

Along the active fault lines, or rather fault systems, displacement can occur either more or less continuously or occasionally, with jumps. Continuous movement is typical of cracks in warmer rocks, while fractures in cooler rocky bodies are rather characterized by occasional sudden jumps. The intermittent displacement, the sudden movement and breaking of the rocks, generates elastic waves. The arrival of these elastic waves – and especially their surface-related components – is perceived as an earthquake. Most of the earthquakes are so small that they are detected only by sensitive instruments; a small part of them are felt by humans, but often do not cause permanent damage to the built environment.

The location of the earthquakes is called a hypocentre, and its surface projection is called an epicentre. The distance between the two is the focal depth, which can extend from the surface to a few hundred kilometres in depth, essentially until the lithospheric plate is solid. The physical size of the earthquake is characterised by the magnitude and its surface effect is the intensity. The magnitude is proportional to the logarithm of the energy released; two differences in magnitude show a thousand-fold difference in the energy released. Although the magnitude scale does not have a formal upper limit, the energy of the earthquake cannot give any large value. The world has not seen a quake of more than 9.6 magnitude, while the size of the 1763 Komárom earthquake, the largest in Hungary, is estimated to have been 6.3 magnitude. The intensity, or macroseismic intensity, is the degree of the effects and damage caused by the earthquake, which changes from place to place. The intensity of the earthquake can be given on the basis of the 12-degree European Macroseismic Scale (EMS), which is the successor of the previously introduced Mercalli scale 7. The maximum intensity of the earthquake is usually found in the vicinity of the epicentre and the intensity decreases with the distance away from it. Among the same energy earthquakes, shallower focal depth, (closer to the surface) produces higher macroseismic intensity. However, in the case of a deeper earthquake, the intensity decreases less with distance from the epicentre.

In the world, the most active seismic areas are along plate boundaries, alongside the moving lithospheric plates. In our wider area, this is the southern foothills of the Alps, in Northeastern Italy. In contrast, the northern and northeastern parts of the region, namely Czechia, Poland, and Ukraine, are essentially aseismic, where earthquakes are known only through reports on the news, with the exception of one or two local seismic zones.

Looking at the spatial distribution of earthquakes in the Carpatho–Pannonian Area, it can be concluded that the region is characterised by moderate but non-homogeneous seismic activity 8. The most seismic areas are the mountainous regions bordering the Pannonian Basin: the southern part of the Eastern Alps, the Mura–Mürz–Žilina line, the Carpathians (mainly the Vrancea Mts.) and the Dinarides (especially in the Adriatic Medvednica zone). The focal mechanisms of



Seismology

Seismology is the science of earthquake observation. Its main purpose is to determine earthquake parameters by collecting and processing earthquake reports, as well as by instrumental recording and observation. The most important parameters of earthquakes are the location of the epicentre (geographical coordinates), the focal depth, the origin time and the physical size of the earthquake, or in other words the magnitude. The observation of earthquakes provides basic knowledge of the nature, causes and distribution of earthquakes, and also allows us to discover the Earth's internal structure by observing earthquake waves.

In Hungary, scientific research on earthquakes can be dated to the M 5.4 Mór earthquake of 1810. Ádám Tomcsányi, professor of physics, and Pál Kitaibel, polymath scientist, went through the area affected by the earthquake to thoroughly assess and describe the extent of destruction. In 1814, they published their Mór earthquake paper and edited the map 1 illustrating the surface effects of the quake. Their paper and map can be considered a milestone in the history of seismology, since it is the first map showing earthquake damage and the scientific conclusions that can be drawn from it. Isoseismal lines show the areas that suffered the most serious damage (areas affected by the same degree of damage). The church towers of the various settlements appear to have partially or completely fallen down, indicating the magnitude of the damage. The small arrows on the map indicate the propagation direction of the waves from the epicenter.

Organised earthquake research – the second in Europe – began in 1881 with the establishment of the Standing Committee on Earthquakes in the Hungarian Geological Society. In 1905, with the support of the Hungarian Academy of Sciences (MTA), Radó Kövesligethy 2 founded the Budapest Earthquake Observatory. At that time, the Hungarian seismological network consisted of 5 stations: Budapest, Fiume (Rijeka), Ógyalla (Hurbanovo), Temesvár (Timișoara) and Zágráb (Zagreb). As of 2017, there are 30 permanent seismograph stations in Hungary, of which 5 are modern borehole seismographs and 25 are surface stations.

1 *Map of the Mór earthquake in January 1810 (1814)*

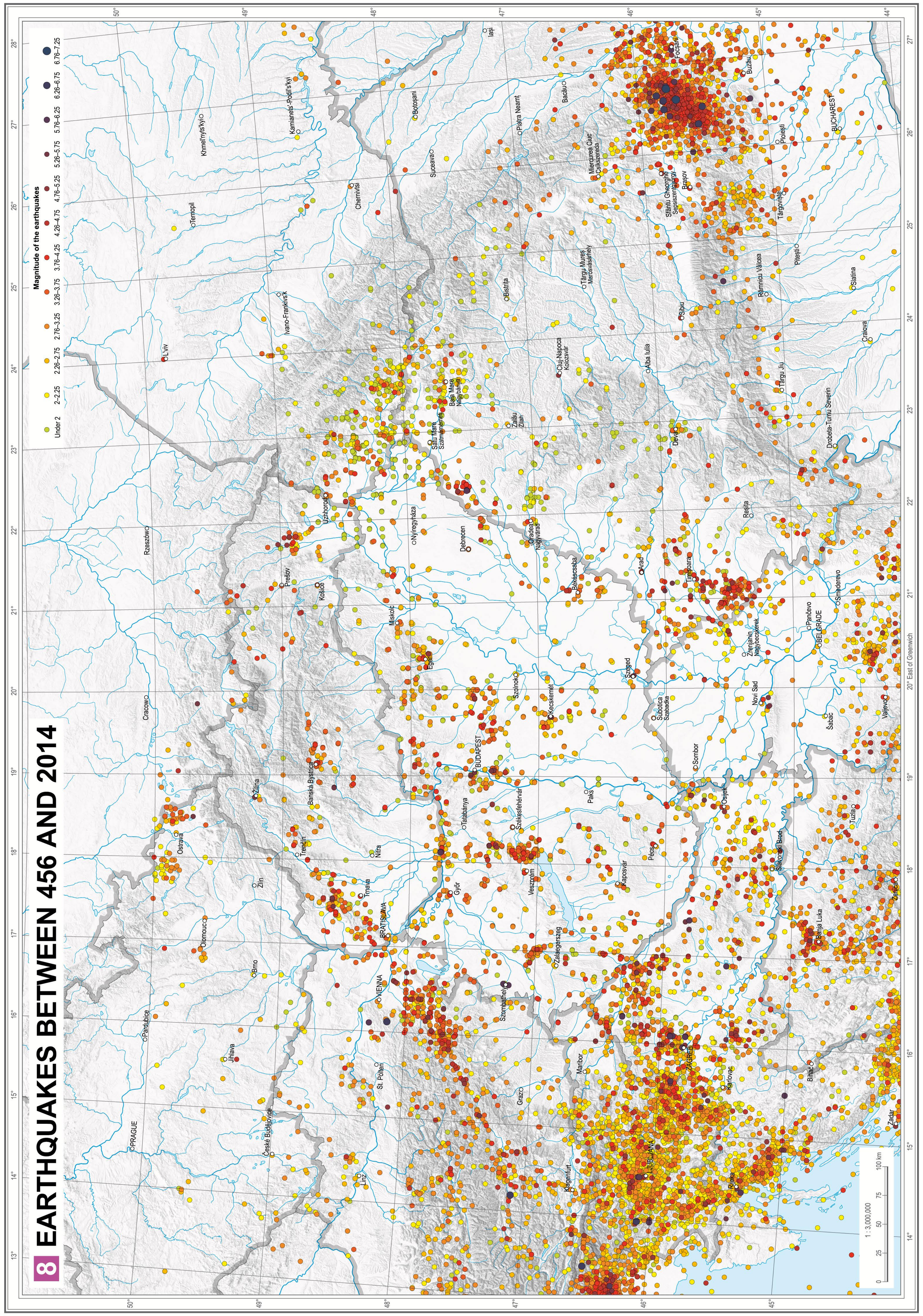
2 *Radó Kövesligethy (1862–1934), the pioneer of Hungarian earthquake research*

Magnitude, Richter scale, moment magnitude

Today's earthquake magnitude scales are based on the scale first introduced by an American seismologist Charles F. Richter in 1935 to characterise Californian earthquakes. The magnitude is proportional to the logarithm of the energy released during the earthquake: a magnitude increase is about 32 times the energy increase. When a 4.5 magnitude earthquake takes place, approximately the same amount of energy is released as when a small atomic bomb explodes (e.g. the 20 kt bomb dropped on Nagasaki). The magnitude of the largest earthquake observed so far (Chile, 1960) was around 9.5. This was equivalent to about 66,000,000 atomic bombs of the above-mentioned size. Nowadays, however, the momentum magnitude (M_W) is most often used to characterise the size of large earthquakes. This can be calculated from the physical size of the earthquake break. In the 26 December 2004 Sumatra earthquake, responsible for a devastating tsunami, the breaking surface was 1,200 km long and 100 km deep, the displacement was 15 m, the seismic moment M_0 was 1.1×1023 Nm, and the M_W value was 9.3.

7 THE 12-DEGREE EUROPEAN MACROSEISMIC SCALE (EMS)

EMS intensity	Definition	Description of typical observed effects (abstracted)
I	Not felt	Not felt.
II	Scarcely felt	Felt only by very few individual people at rest in houses.
III	Weak	Felt indoors by a few people. People at rest feel a swaying or light trembling.
IV	Largely observed	Felt indoors by many people, outdoors by very few. A few people are awakened. Windows, doors and dishes rattle.
V	Strong	Felt indoors by most, outdoors by few. Many sleeping people awake. A few are frightened. Buildings tremble throughout. Hanging objects swing considerably. Small objects are shifted. Doors and windows swing open or shut.
VI	Slightly damaging	Many people are frightened and run outdoors. Some objects fall. Many houses suffer slight non-structural damage like hair-line cracks and fall of small pieces of plaster.
VII	Damaging	Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many well-built ordinary buildings suffer moderate damage: small cracks in walls, fall of plaster, parts of chimneys fall down; older buildings may show large cracks in walls and failure of fill-in walls.
VIII	Heavily damaging	Many people find it difficult to stand. Many houses have large cracks in walls. A few well-built ordinary buildings show serious failure of walls, while weak older structures may collapse.
IX	Destructive	General panic. Many weak constructions collapse. Even well-built ordinary buildings show very heavy damage: serious failure of walls and partial structural failure.
X	Very destructive	Many ordinary well-built buildings collapse.
XI	Devastating	Most ordinary well-built buildings collapse, even some with good earthquake resistant design are destroyed.
XII	Completely devastating	Almost all buildings are destroyed.



8 EARTHQUAKES BETWEEN 456 AND 2014

the earthquakes show that in the southern part of the Eastern Alps and in the Dinarides strike-slip and thrust faulting are almost exclusive, with the maximum horizontal stress directions being N–S and NNE–SSW. This can be explained by the collision of the Adria microplate and the Eurasia plate. The Vienna Basin is characterised by strike-slip faulting with NNW–SSE and N–S directions of the largest horizontal stresses.

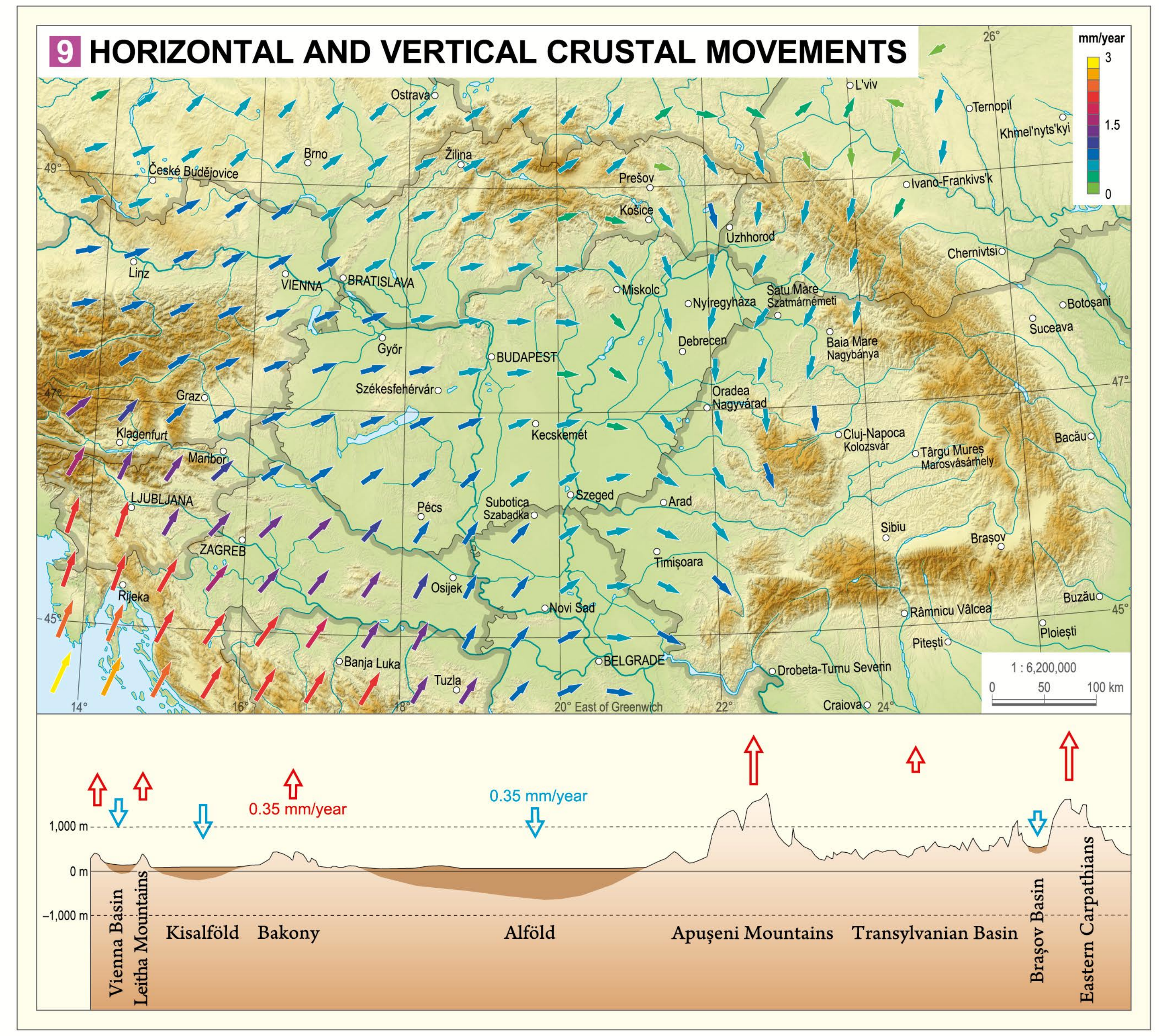
Throughout the area, earthquakes are distributed in the upper part of the crust, in shallow depths between 6 and 15 km. An exception to this is the earthquakes of the Vrancea region, characterised by intermediate depth seismicity: strong earthquakes occur either in the 70–110 km or 125–160 km depth domains. In this highly seismic area, earthquakes of magnitudes 5 occur almost annually, and magnitudes exceeding 7 are not exceptional (e.g. M 7.2 in 1977, M 7.0 in 1986, M 7.6 in 1990). These earthquakes are due to a descending relic slab beneath the Vrancea region.

The instrumental observation of earthquakes began only at the beginning of the 20th century with the development of modern seismographs. Most of the earthquakes known in the Carpathian Basin were recorded in historical times before the period of instrumental measurements.

According to historical data and instrumental measurements, the highest seismic activity in today's Hungary is visible along the area from the eastern end of Lake Balaton to Komárom. Recently two relatively large quakes (Berhida, 1985, M 4.9; Oroszlány, 2011, M 4.5) occurred here, and the most important historical earthquakes (Komárom, 1763; Mór, 1810) were also recorded in this area. Szombathely (456), Érmellék (1834), Kecskemét (1911), the southern outskirts of Budapest (Dunaharaszti, 1956), parts of Heves County, and more recently the area of Nógrád County are the main areas affected by earthquakes. The chapter of the Atlas on *Natural Hazards* deals with Hungary's earthquake hazard and with these historical catastrophes.

Crustal movements

The regional effect of the lithospheric slab movements governing the whole surface of the Earth can be detected by repeated measurement of the geodetic reference frames (the coordinates of the geodetic basepoints, fixed in the field). We can detect the horizontal and vertical components of these movements. To measure them, different tools are used by traditional geodesy. The horizontal position of the basepoints is determined by triangulation, while their elevation is given by precise levelling. By repeating the measurement of an existing reference frame, we gather information about the difference of the horizontal and vertical positions of the points existing in both the old and new frame. As a result of crustal deformations, the detected angles of the trigonometric network are also changed, which is also a good addendum to our analysis. The change in the horizontal position of the basepoints refers to the plate motions. In the case of plate collision zones such as the Pannonian Basin it also shows the territorial distribution of the caused deformation. The elevation changes of the basepoints show the velocity of the mountain building or – in the case of basins – the velocity of their subsidence. In modern geodesy, instead of the separated measurement of the horizontal and vertical positions of the basepoints, we locate them in a three-dimensional space by space technology (GPS).



9 HORIZONTAL AND VERTICAL CRUSTAL MOVEMENTS

The worldwide horizontal plate velocities are on the order of a few cm/year. However, in the Carpatho–Pannonian Area – a lithospheric part moving together, affected by some deformation forces – the internal velocity differences stay below 0.5 cm/year. There are relatively rapid movements in the Dinarides as a result of the push from the Adriatic, a part of the African plate. The deformations turn gradually eastward and south-eastward and become slower in the central part of the basin 9. The eastward decrease of the deformations refers to the compressional character of the Pannonian Basin. The western and eastern flanks of the basin are approaching each other by 1.5–2 mm/year. Thus the basin acts as a 'bumper'; the energy from the African–Eurasian collision is transformed to its deformation.

This picture is completed by the database of vertical movements, which is still marred by high uncertainties. It shows generally that the basin, characterised by thin crust and lithosphere and by compression, is folding in waves like a paper sheet pushed together from two sides. The central part is quickly subsiding. The neighbouring mountains, the Transdanubian Range and the Apuşeni Mts., are moderately uplifting. The subsequent sub-basins, the Kisalföld and the Transylvanian Basin (Tableland), are subsiding again 9. The probable maximum uplift rate is around 0.3–0.35 mm/year in the mountain range axes, while the subsidence is of the same or a bit higher extent. The area of the Alföld, which is affected by artesian water and hydrocarbon exploitation, is quickly subsiding now, beginning since around the beginning of the 20th century, because of the induced compaction. The current subsidence speed is a few mm/year in some points.

In summary, active geodynamical and neotectonic processes, the movements of the surface and of subsurface bodies have important societal aspects. Their effects are seen in the economy and must be considered in risk analysis and risk management. The most apparent application is seismic risk assessment, where the important input data are the historical and instrumental earthquake recordings. However the rule of thumb that 'the more quakes in the past means higher probability in the future' does not cover the whole spectrum of the risks. Knowledge of the neotectonically active faults, verified by geophysical measurements, expands the area at risk or at least the zones to be classified by more detailed research. Second, our knowledge about the formation and geodynamical history of the region provides good results in hydrocarbon mining and in the estimation of hydrocarbon potential, for both traditional and deep reservoirs to be surveyed by new technologies. Finally, knowledge of the vertical movements is important for flood and inland flood defence strategies.

The subsidence centres of the Alföld act as natural river valleys. However, in a geological time scale their differential subsidence was equalised by the sedimentation of the inundated area. When a region was passed over in this equalisation process and became relatively lower in elevation, river course changes occurred, thus covering the whole subsiding zone. Due to flood control measures, the river courses were more or less 'fixed', thus decreasing significantly the area of possible sedimentation – and subsidence equalisation. Simultaneously, the original natural subsidence was quickened by the groundwater and by hydrocarbon exploitation-based induced compaction. Moreover, the amount of compaction varies in the area, with the maximum effect being detected around the cities of high water consumption. The process changes the longitudinal section of the rivers, changing the characteristics of the floods and usually worsening the situation. Meanwhile, the areas of the plain that are subsiding and not being supplied with new sediments are more and more endangered by floods and excess water.

III.

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