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Tamas Jasko editor
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Environmental Study of Valley Fill Sediments

S. Jasko
H-1122 Budapest XII.,
Pethényi köz 4, Hungary

Abstract

The study of Pleistocene and Holocene fluviatile deposits in river valleys is important for environmental protection. Well records allow the mapping of clay, sand, and gravel beds under recent valley floors. Such surveys can also locate active tectonic zones. This technique helps in assessing potential seismic hazards for large industrial sites.

The study of fluviatile sediments under recent valley floors is relevant to environmental studies for another reason as well.

The permeability characteristics of these formations have a decisive bearing on the spreading of various pollutants entering the rivers or the groundwater along the rivers. Thus, the knowledge of subsurface formations is essential for the siting of factories with dangerous products and deposits of hazardous waste.

Fluviatile sediments along the Hungarian stretch of the Danube Valley have been explored by thousands of shallow boreholes. These allowed the geotectonical and hydrogeological study of sites for completed and planned dams and nuclear power stations and assessing potential environmental hazards.

Storage of radioactive waste and forecasting of seismic hazards for human settlements are among the most challenging questions of environmental geology.

This is shown by the fact that at the 1989 International Geological Congress in Washington more than a dozen papers dealt with the accuracy of seismic hazard assessment for large installations, e.g., nuclear power stations and dams. It was generally accepted that the magnitude of risk is a function of regional seismicity and neotectonic structure (Abstracts of the 28th International Geological Congress, Vols. I-III).

Recognition of intervals of tectonic activity is considerably helped by the study of sediments that lie under recent valley floors. Under normal circumstances these silt, sand, and gravel beds form contiguous horizontal or sub-horizontal bodies.

Consequently, wherever the thickness or the horizontal width suffers abrupt changes at lines traversing the valley it is an indication of post-deposition movements.

Valley floor deposits are essentially different from hillside loess and weathering deposits. These hillside deposits did not originate as horizontal beds of uniform thickness.

The change of height of high-lying river terraces was used at some places to deduce vertical movements in the recent geological past. River terraces are, however, difficult to trace over long distances. Usually, terraces are preserved only as isolated patches. In contrast, fluviatile deposits under the valley floor can form contiguous, several-kilometer-wide zones in major river valleys. As such they are excellent indicators of recent and sub-recent tectonic activity.

Another important environmental aspect of the study of sediments found in valley floors is due to the influence of the permeable or impermeable nature of these formations on the deep spreading of groundwater pollutants. The study of valley floors is therefore imperative to the location of industrial plants producing hazardous materials and for the designation of storage sites for hazardous waste.

Lower Pleistocene terraces found high on hills bordering the Danube Valley have been extensively studied by Pécsi (1959), Kretzoi and Pécsi (1982), and Rónai (1986). The uppermost Pleistocene and Holocene deposits underlying recent valley floors have, however, not been concisely evaluated until recently (Jaskó 1990; Jaskó and Kordos 1990; Jaskó and Krolopp 1991). This study was made possible by the drilling of several thousand precisely located boreholes with stratigraphic logs.

The author had access both to the published literature and unpublished drilling records deposited in the archives of the Geological Survey of Hungary.

The boreholes were drilled at various times and with differing objectives, including exploration for building materials (mainly gravel), water supply, and geological surveying. The data are scattered in numerous reports. Extraction and critical evaluation of the data was a time-consuming task. Only after the completion of this stage was it possible to construct reliable contour maps of formation thickness and base and to use these maps to find the position and extent of neotectonic fault lines.

The last stage in the investigation was to compare the findings in the river valleys with the structure of the adjacent region and analysing the history of sedimentary cycles of alternating erosion and accumulation periods to trace stratigraphic gaps.

The Danube river traverses terrains of contrasting geological composition, which is reflected in variations of valley width and thickness of valley floor deposits (Fig. 1). Three basic types can be distinguished:

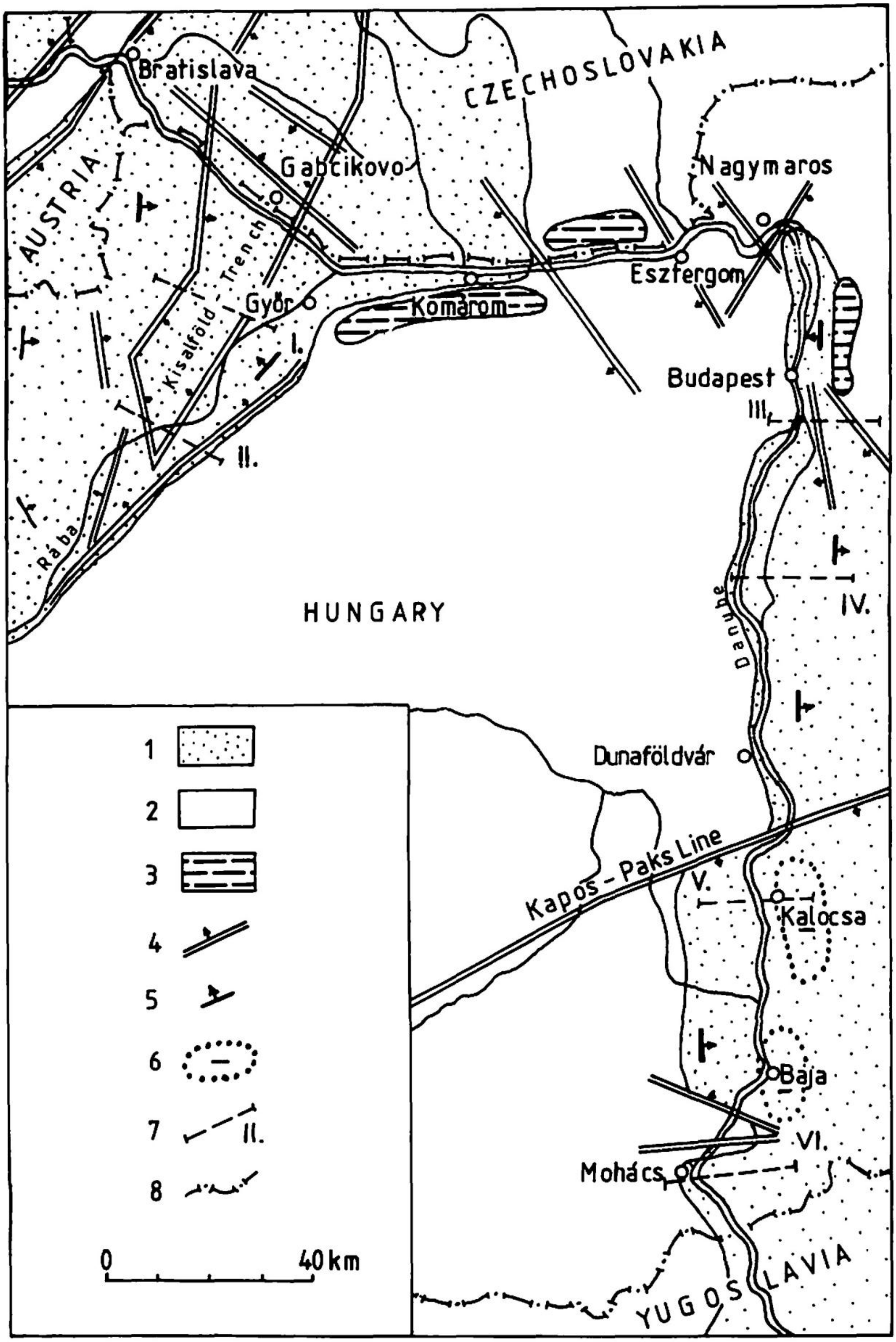
l. Where the river cuts across ranges of hills, the valley is narrow. The steep slopes show remains of old terraces. Sediments on the recent valley floor are thin or non-existent, so that at some places the river bed is cut into the bedrock.

2. Margins of the plains are covered by relatively thin Upper Pleistocene to Holocene gravel beds of wide provenance. The gravel is deposited on the smooth planar surface of Pleistocene or older formations with an erosional gap.

3. In the basins the Upper Pleistocene and Holocene gravel gets gradually thicker, reaching up to 50-60 m. The basin floor under the gravel formation is cut at places by tectonic grabens, which are filled by Lower Pleistocene and Upper Pliocene fluviatile sediments.

It follows from the above that the only formations that can be traced along the entire length of the Danube Valley are of Upper Pleistocene to Holocene age. These beds are the result of a single depositional cycle.

Figure 1. The Danube Valley between Bratislava and Mohács.
Sketch of Quaternary structure. l. Quaternary fluviatile sediments; 2. exposed Tertiary and Mesozoic formations; 3. terrace remains contiguously traceable over a large area; 4. young faults; 5. dip of Quaternary fluviatile formations; 6. synclines; 7. line of geological cross sections; and 8. international boundaries.


Bratislava
CZECHOSLOVAKIA
Gabcikovo
Nagymaros
AUSTRIA
Kisalföld Trench
Eszfergom
Győr
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I.
Budapest
III.
II.
Ráb a
Danube
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HUNGARY
1
2
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5
6
7
8
II.
0
40km
Dunaföldvár
Kapos - Paks Line
V.
Kalocsa
Baja
VI.
Mohács
YUGOSLAVIA

Grain size diminishes from bottom to top. There are big boulders on the bottom, followed by gravel, then comes sand, and, finally, fine silt. This Upper Pleistocene to Holocene sedimentary cycle was preceded by a long stage of regional erosion.

In the past it was erroneously assumed that in the basins the fluviatile sedimentation of the Danube produced continuous sequences without gaps. A similarly false hypothesis stated that the gradually sinking continuation of hill-slope terrace remains can be followed without break in the basin sequences. Actually, there is a zone between hill and basin where there are no terraces, but the basin sequence is yet incomplete. Old terraces have been destroyed here by regional erosion prior to the deposition of Upper Pleistocene sediments.

Structural connections between Tertiary rocks and the covering Quaternary fluvial deposits are easily established. Where the boundary of Tertiary and Quaternary disappears in the deeper subsoil, the fluvial deposits gradually become thicker to fill the sink. Fault locations observed in Quaternary sediments correspond to the main faults in Tertiary rocks.

Quaternary dislocations are weak revivals of the large-scale Tertiary movements.

A few examples will now be presented of the effect of neotectonic conditions on the safety of industrial complexes along the Danube. As the main aim of this paper is to describe the new technique, these examples are restricted to a summary of results. Detailed background information can be found in other papers published by the author (see References Cited).

Such a short summary with a few figures can only give a rough sketch of these problems. A comprehensive engineering and environmental geological study would incorporate further drilling and geoelectric surveys in each particular case.

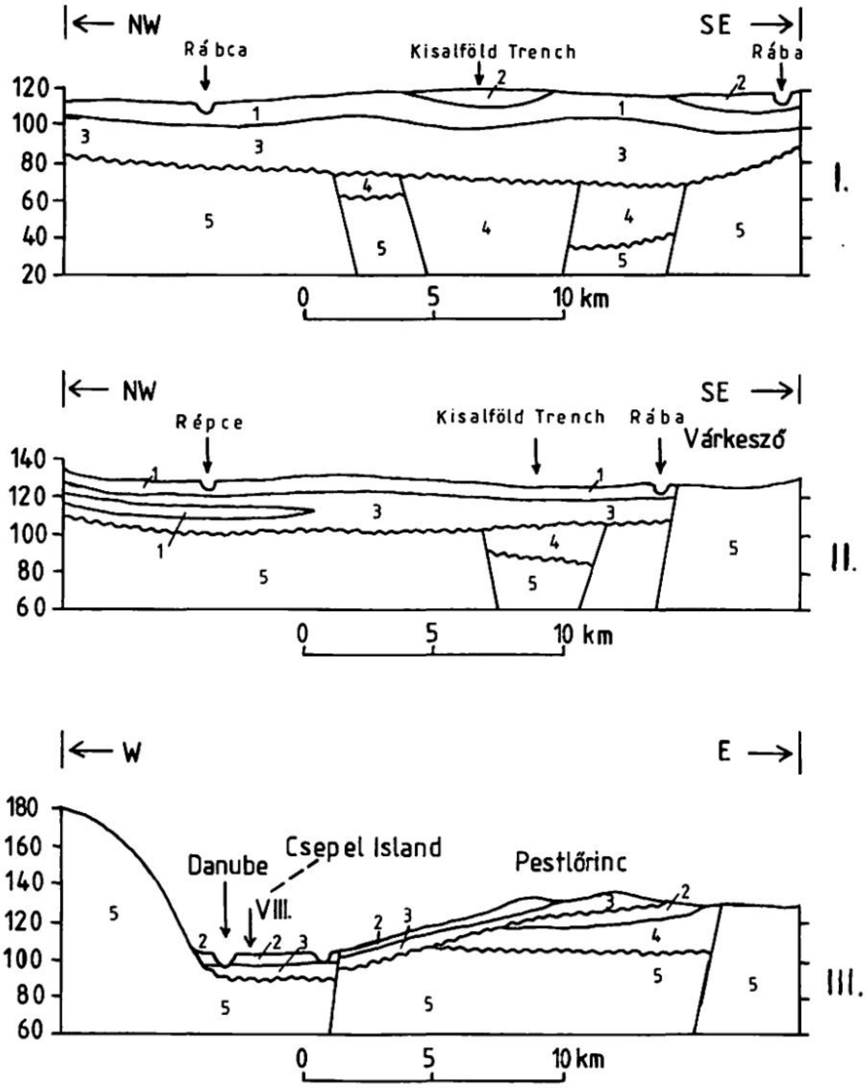

Figure 2. Geological cross sections.

I. central part of the Little Hungarian Plain graben; II. southern end of the Little Hungarian Plain graben; and III. southern outskirts of Budapest. 1, clay; 2, sand; 3, gravel; 4, Lower Pleistocene (older) gravel; 5, undifferentiated Pliocene and Miocene under the gravel formations. Heights in meters above sea level.

Between Bratislava and Győr there is a plain that is 60-70 km wide. It is covered by Upper Pleistocene and Holocene gravel deposits about 20-30 m thick.

Under the gravel there is a 20-km-wide and 100-km long graben. The graben is filled by Lower Pleistocene gravel, which may be up to 100 m thick. The southern part of the plain and the graben is in Hungary, the northern part in Slovakia (Figs. 2 and 3).

Such a structure of an Upper Pleistocene gravel covering the whole extent of the plain and a smaller graben filled by a Lower Pleistocene gravel body can also be found in the Vienna basin (Thenius 1974).

Thus, these neighbouring regions have identical geological structures and developed along similar lines. The marginal faults of the graben in the Little Hungarian Plain ceased activity in the Upper Pleistocene and Holocene. The modern riverbed of the Danube is nearly perpendicular to the graben. On the other hand, faults of NW-SE direction were found in Czechoslovakia and have influenced modern surface drainage patterns (Myslil 1958).

The Gabcikovo Dam lies in the centre of the Little Hungarian Plain, and studies were commissioned to analyse structural conditions and to estimate future subsidence around the dam and sedimentation in the reservoir (Varga 1981). Detailed geological and seismic surveys formed part of the planning stage. The surveys revealed some faults, which led to changes in the plans and resiting of the dam.

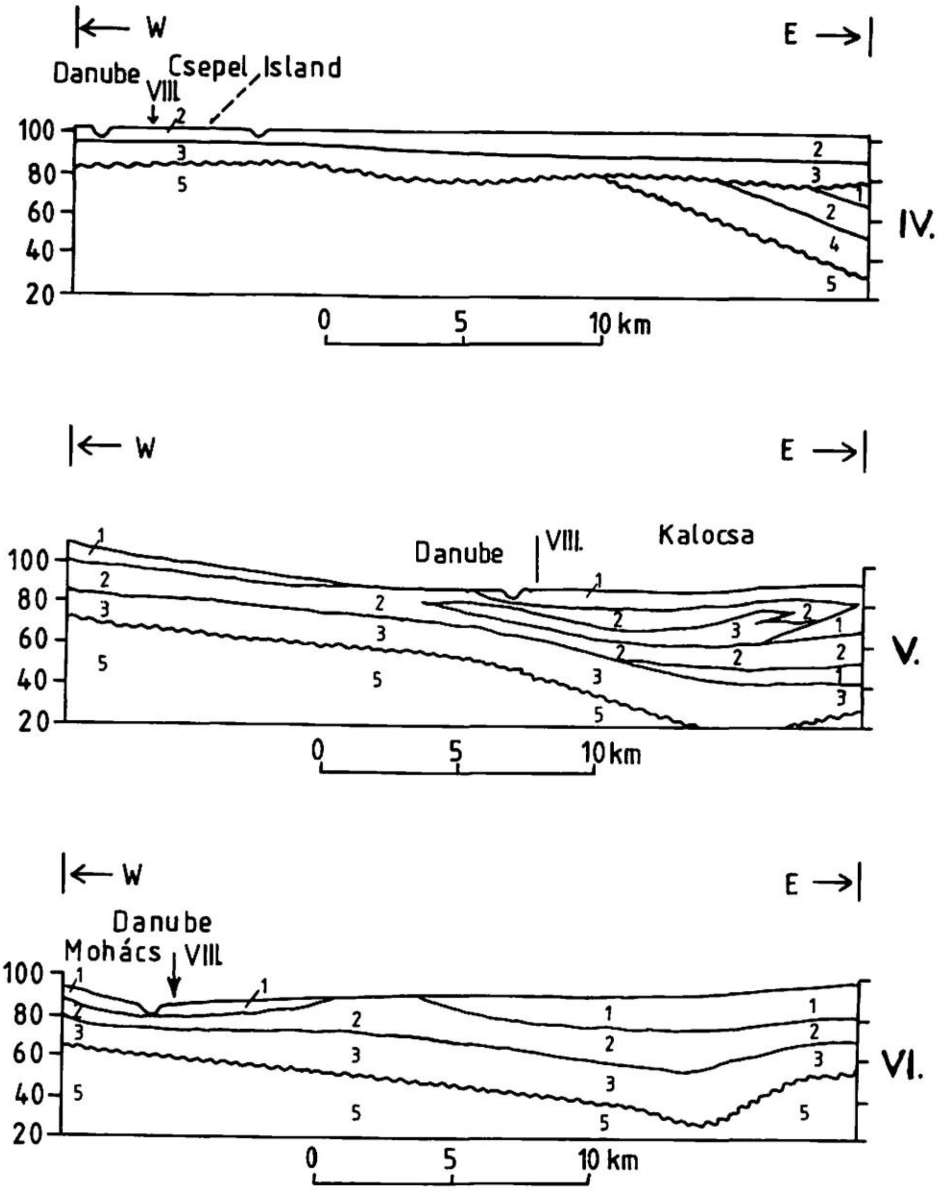

Figure 3. Geological cross sections.
IV. Csepel Island; V. near Kalocsa; and VI. near Mohács. 1, clay; 2, sand; 3, gravel; 4, Lower Pleistocene (older) gravel; 5, Pliocene under the gravel formations. Arrows indicate position of section VIII. Heights in meters above sea level.

The consequences of building a reservoir with its water level above the surrounding plain were ignored in the planning stage. Construction was well under way when the environmental impact of rising groundwater levels was first assessed, revealing the damage to agriculture and forestry in the area surrounding the dam. Further details of this controversial and economically important project are outside the scope of this paper. The environmental impact of storage dams is the subject of wide-ranging literature on its own (Castle-Clark and others 1980, Novosad 1989).

Further downstream, another dam was planned for the Nagymaros site, 100 km east of Gabcikovo. The Danube crosses a prominent range of hills here. The river's width and direction is frequently changing according to the softer or harder nature of the bedrock over a mosaic of horst and graben faulted basement structure (Jaskó 1990). At some places the alluvial valley floor is only 1000 m wide between the steep slopes; at other places its width may be 2-3 km.

The thickness of the gravel beds is also very variable. There are places where the gravel is so thin that the modern river bed is cut into the Tertiary bedrock. The dam at Nagymaros was to be constructed at exactly such a spot. After the construction started, it was found that the andesitic bedrock is criss-crossed by faults. While the original plans called for simultaneous construction of dams at both Gabcikovo and Nagymaros, the unforeseen environmental and technical problems hindered progress.

Figure 4 is a geological section of the valley between Gabcikovo and Nagymaros. It shows that the base of the gravel is gradually rising from west to east. In other words, the gravel was deposited in a valley that was apparently sloping in the opposite direction to the flow of present day Danube.

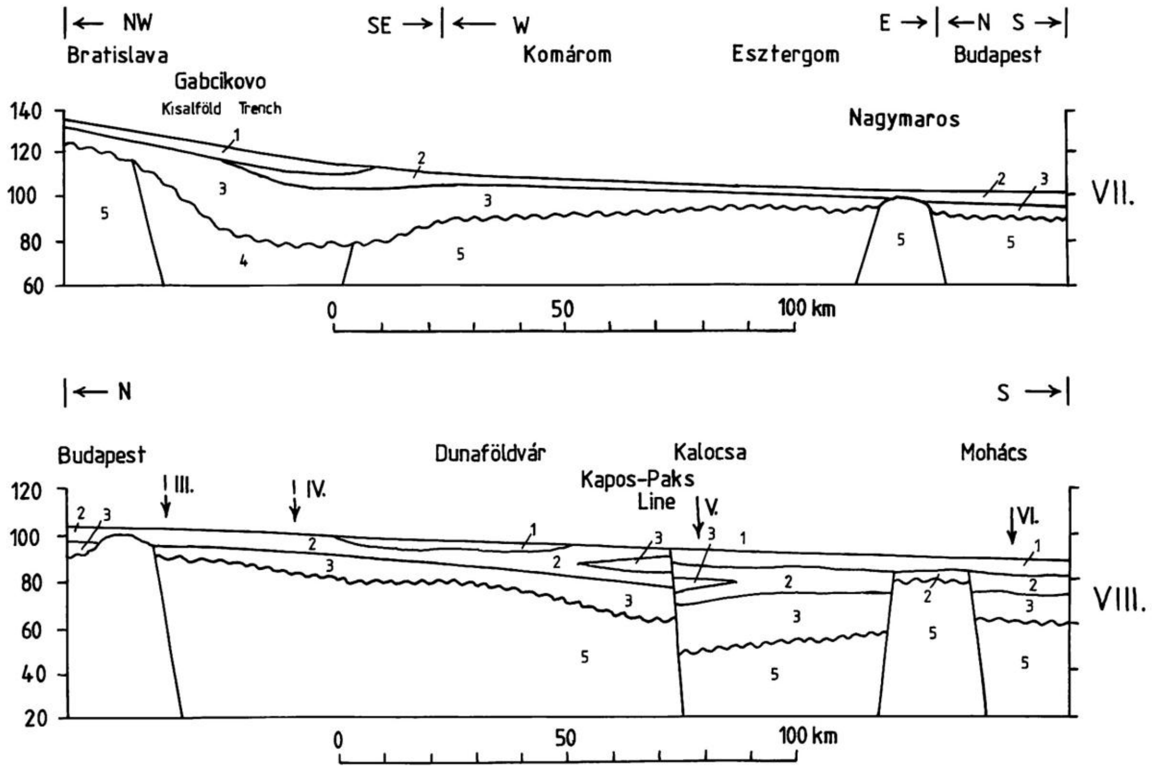

Figure 4. Geological sections along the present course of the Danube. VII. from Bratislava to Budapest; VIII. from Budapest to Mohács. l, clay; 2, sand; 3, gravel; 4, Lower Pleistocene (older) gravel; 5, subcrop under the gravel formations: undifferentiated Pliocene, Miocene, and Oligocene. Arrows indicate positions of sections III-VI. Heights in meters above sea level.

This strange situation can only be explained by assuming that the lopsided subsidence of the area continued throughout the Holocene period. The Danube could only keep flowing eastwards by filling the gradually sinking basin with sediment.

A large fault of NW-SE strike crosses the valley at Esztergom. This fault is near the proposed site for a new nuclear power station on the north bank in Slovakia (Hrasna 1987). It remains to be fully investigated whether movement along this fault ceased in the Lower Pleistocene or continued till the Holocene.

Quaternary rocks of the Dunaföldvár to Mohács section have been affected by two kinds of tectonism. First, there was continuous subsidence slow enough for sedimentation to keep pace with it. Such subsidence created the Kalocsa and Baja cauldrons. Secondly, there were sudden fault movements relocating rock masses. Probably the most important fault in the area is the Kapos-Paks line, crossing the Danube valley near the Paks nuclear power station (Fig. 1). Drilling and geophysical surveys long ago traced this NE-SW striking structural lineament for hundreds of kilometres in the Paleozoic and Mesozoic basement.

The effect of transcurrent movements was also observed in Pliocene formations (Némedi Varga 1977, 1986; Pogácsás and others 1989). It was an important challenge for environmental geologists to find out whether all transcurrent movements ceased at the end of the Pliocene, or perhaps that the fault was still active, reviving from time to time, albeit perhaps with less intensity.

My investigations found a sudden change in the Holocene fluviatile formations occurring at a clearly defined fault line at Paks. As shown by maps of the Upper Pleistocene gravel based on shallow borehole data, the base of the gravel is higher everywhere on the north side of this line than on the south side. The direction of contour lines is also different on both sides of the line (Jaskó 1990; Jaskó and Krolopp 1991).

Figure 5 is a block diagram that explains the situation. The upper part shows the current state, and the lower part is a hypothetical reconstruction. In this reconstruction the area south of the Paks fault is shifted 17 km to the east to give the best fit between data on both sides of the fault.

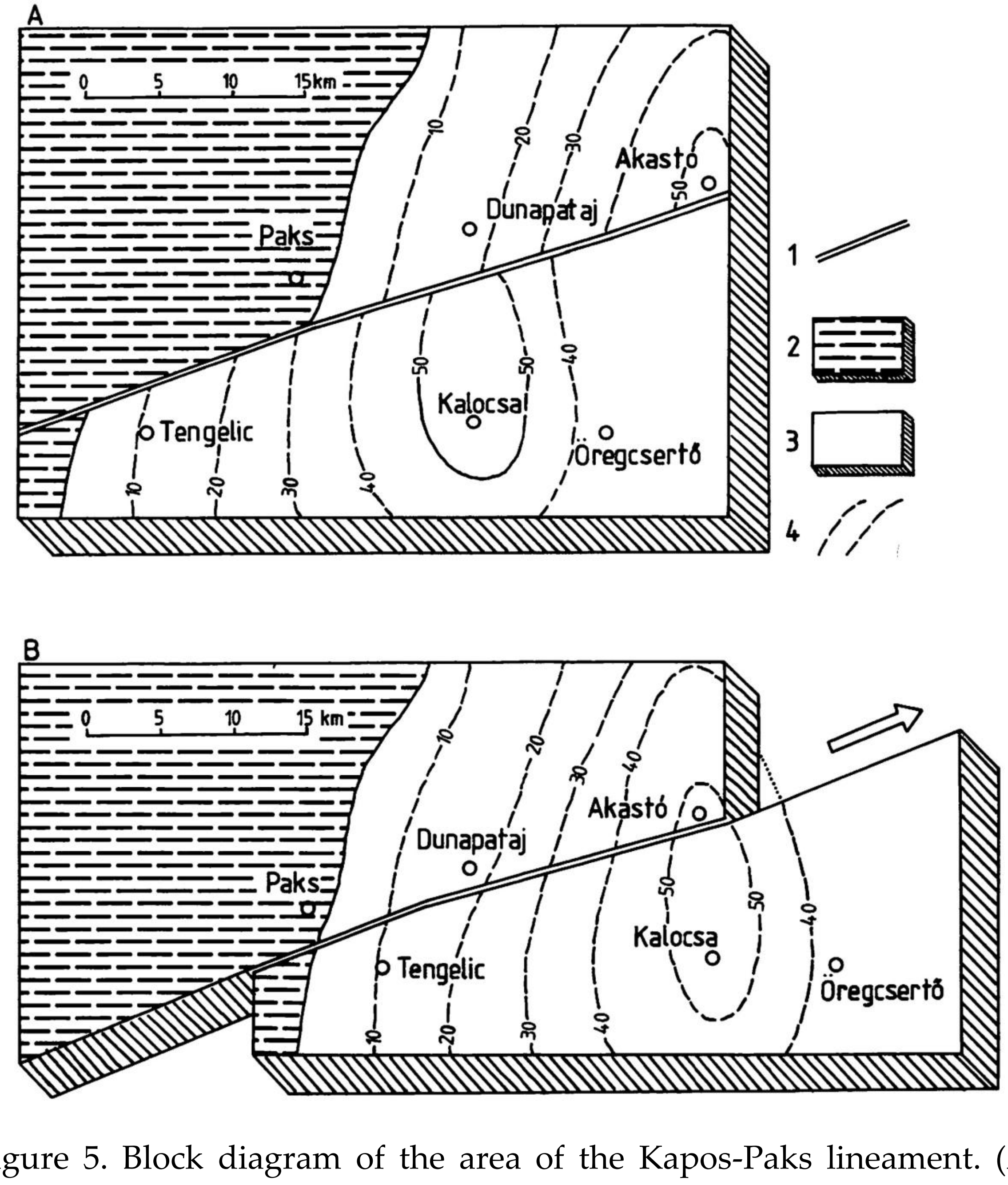

Figure 5. Block diagram of the area of the Kapos-Paks lineament. (A) Actual position; (B) reconstruction of previous position with the area south of the Kapos-Paks lineament moved back to the east into its assumed original position. 1. Kapos-Paks lineament; 2. area devoid of gravel; 3. area covered by the gravel formations; and 4. thickness contours of the gravel formation (meters).

It is worth noting here that available geophysical data and drilling records do not give a precise location for the basement lineament.

Studies in other parts of the Danube basin have repeatedly established close connections between Quaternary tectonic patterns and older structural trends. It is quite likely that at Paks too, the position of the deep transcurrent structural line matches that of the fault in shallow Quaternary formations.

Further palaeogeographic studies, geoelectric surveys, and drilling are needed to construct detailed seismotectonic maps and environmental evaluation of this specific site.

With the limitations outlined above, the block diagram reconstruction is just a hypothesis - a possible explanation of the abrupt changes in sedimentation pattern. Even so the results so far give a clear warning: a better assessment of seismic risks is needed before the planned expansion of the Paks nuclear power station takes place.

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