GROUNDWATER—GEOGRAPHICAL AND HYDROGEOLOGICAL CONDITIONS OF THE TALUS SYSTEM OF THE RIVER MAROS

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It is well known that the groundwater reserves and the groundwater courses play extremely important roles in the supply of water for mankind. The melioration operations on agricultural, areas, the intensity of salinification and marshification processes on the Great Hungarian Plain, etc. are direct functions of the variations in the prevailing extent and time of the groundwater level.

The aims of this work are to clarify the groundwater-geographical problems of the talus system of the Maros, and to evaluate the characteristics of the groundwater courses, and the interactions of the water-course components typical of the subsurface currents.

The area of the Maros talus in one of the most characteristic groundwater-geographical regions of Hungary. An important factor in its development was the fracture subsidence on the edge of the Great Hungarian Plain in the fore-area of the Transylvanian Sziget Mountains, which led to significant differences in levels. In the course of the Pleistocene, the rivers running off the Transylvanian Sziget Mountains and their environment partially filled in these differences in levels with river alluvium. This is how the talus of the Maros was formed, which can be traced in a northerly direction at a very great distance from the present river, all the way to the line Békéscsaba — Hódmezővásárhely (Fig. 1). The peak of the talus, spreading out fanwise, is found above the level of the Great Hungarian Plain at Radna, at a height of about 230 m above sea-level. This height means a difference in level of about 100 m in the talus system, which spreads out roughly in a semicircle with a radius of about 80—100 km, and slopes in every direction. Tracing-out of the limits of the talus is weakened by the variants of the Pleistocene debris-powder formations (infusion loess formations). The limits of the talus are the sharpest on the northern and north-eastern edges, where the limiting line appears in the dune strata rising out of the level.

On the area of the talus the river alluvium accumulations can be found even in the upper levels of the Levante layers. These gravelly deposits confirm intensive river-filling work. Onto the Levante gravelly deposit a Pleistocene gravelly layer settled; however, this exhibits a finer structure in grain composition and in particle distribution.

In the Pleistocene the deposition of gravel recurred several times, and the filling-in work of two significant river sections is reflected by the exposed layer structure. The first talus formation (gravelling-up) main section occurred at the end of the Levante and in the Lower Pleistocene period. As regards both the thickness development and the areal extent, this older talus formation differs considerably from the

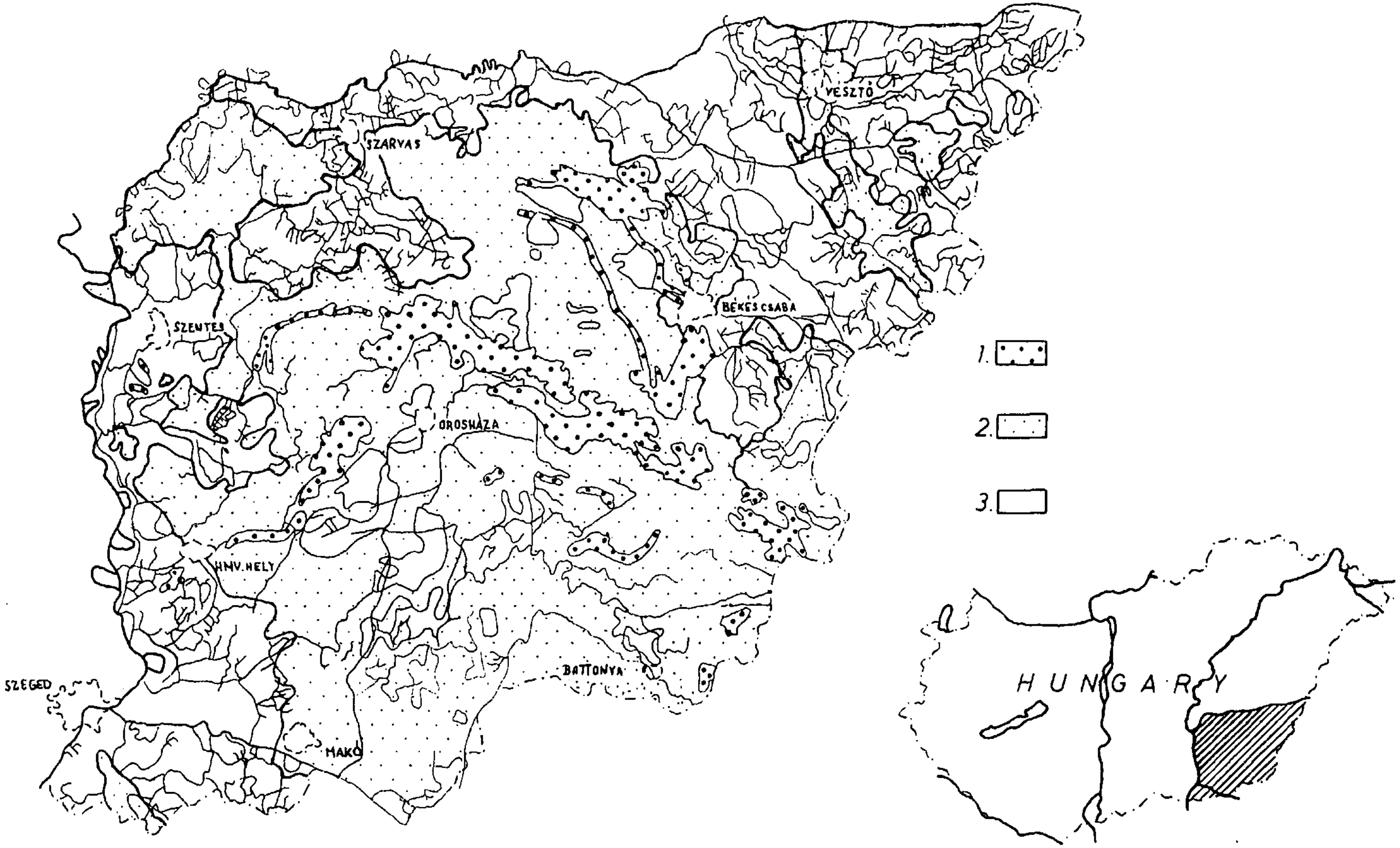


Fig. 1. Hungarian area of the Maros talus, with indications of the porosity of the sediment near the surface.
1. Sediment with good water permeability: $K = 10^{-3}$—10^{-4} cm/sec.
2. Sediment with moderate water permeability: $K = 10^{-4}$—10^{-6} cm/sec.
3. Sediment with poor water permeability: $K = 10^{-6}$—10^{-8} cm/sec.

Fig. 7. Geomorphological map of the Sajó—Bódva Interfluve. 1 = summit surfaces of low peneplanated block mountains; 2 = plateaus of peneplanated Mesozoic horsts; 3 = surfaces of horsts, mountain crests; 4 = sharp downthrusts of horsts (facets); 5 = summit surfaces of hills; 6 = pediment (remnants) 7= erosion-derasion interfluvial ridge; 8 = low flood-plain; 9 = high floodplain; 10 = river terrace no II/a; 11 = river terrace no II/b; 12 = river terrace no III; 13 = river terrace no IV; 14 = river terrace no V; 15 derasion valley; 16 = erosion valley, gorge; 17 = erosion stream; 18 = erosion-derasion valley; 19 = karst forms in general; 20 = karrenfeld (lapiés); 21 = doline (uvala); 22 = line of bathycapture; 23 = mouth of cave of longer distance; 24 = slope in general; 25 = slope on barren rock; 26 = eroded slope; 27 = unstable slope; 28 = major landslide; 29 = slope with sliding hazard; 30 = river 31 = type of river reaches; 32 = lake, swamp; 33 = major strip mine; 34 = major settlements.

structure composed predominantly of mud, clay and a little gravel in the higher layers. The two main gravelling-up sections of the Lower Pleistocene, and the layer structures of these, produce a rich water-yielding layer formation. The first such gravel layer occurs at a depth of 300—500 m, and the second at 170—250 m.

These gravelling-up stages coincided with the more intensive subsidence phases on the Great Hungarian Plain, but at the same time they were also accompanied by the relative elevation of the mountainous background.

The greater lowering of the bed during the subsidence of the erosion base increased the working capacity of the water flow, and altered its stage natur. The resulting changed conditions led to the enhancement of the progress of the filling-in. With the filling-in of the area a new deposit accumulation ensued on the base level, corresponding to the period prior to the subsidence; this was accompanied by the decrease of the grain size of the transported material, i. e. it became finer. This process of surface development determined the main features of the layer structure and composition of the talus.

The gravelly layers deposited at the different depths confirm the stagewise subsidence of the talus area. The extent of subsidence was most intensive in the Lower Pleistocene, but less so in the Middle and Upper Pleistocene, and in connection with this the thickness and particle size of the gravel layers too are lower. The relative absence of the gravel layer in these upper layers, however, does not exclude the accumulation of coarse-grained sand, which attained a significant magnitude in the central part of the talus and in its south-eastern peak.

The youngest stage of the talus development occurred in the subsidence recurring at the end of the Pleistocene and in the Old Holocene. In this period the water courses flowing down from the mountainous region spread the younger alluvial material onto the older talus. The relatively uniform subsidence of the bottom of the Great Hungarian Plain basin in this period was followed by the river's cutting into the mountainous area and through the earlier talus. This surface transformation resulted in a correlated cyclic deposit-formation mechanism with a fluvial autodynamism. Depending on the extent of the subsiding basin, the deposit cycles were sedimented in part on top of, and in part beside one another. In spite of the different subsidence rates and the local variants, the layer thickness of the individual cycles were approximately identical.

Since, the Maros repeatedly processed and graded the upper deposited material of the old talus, secondarily deposited fluvial sedimentation occurred. A significant role in this transformation of the terrain level was also played by deflation. In the young talus, however, this resulted in a deposit of finer porosity, as regards both the development of the thickness and the areal distribution. In the series of layers of the younger talus the frequency and extent of the gravel deposit decrease considerably, and the sand deposit becomes predominant; in places this is strongly mixed with clayey, muddy sediments. In general this is the characteristic structural picture of talus formation in the Upper Pleistocene (Fig. 2).

In a regional distribution the coarse fraction predominates in the vicinity of the surface in the south-eastern section adjacent to the national frontier. Here sand with various particle sizes and also gravelly sediments occur in the upper layer levels. Since the horizontal subdivision of the talus is well discernible here, analysis can readily be carried out in connection with the groundwater currents and the groundwater reserves. The coarser sediment formed in this area is a consequence of the fact that the water-course emerging onto the Great Hungarian Plain developed a lower-section character as a result of the slight bed lowering. This led, however, to the deposition of a considerable proportion of the alluvial material, with a grading corresponding to the given section nature. At the same time, this also means that the particle size of the deposited sediment decreases with the increase of the distance from the ablation area. The coarse gravel and gravelly formation predominating on the edges and the parts at the feet of the mountains are progressively transformed into sand, and then clay layers on proceeding towards the interior of the basin. With regard to the fact that the basin of the Great Hungarian Plain projects well beyond the present borders of the country, the coarse-grained gravelly fraction lying close to the surface of the Maros talus is found virtually completely in areas outside Hungary (Fig. 3).

From studies of the alluvial material it also proved possible to make a good reconstruction of the very early geographical conditions of the area. The old Maros entered Hungary in the region of Lőkösháza — Battonya, at a great distance from its present valley. The main and side arms then flowed in a north-westerly direction, and the alluvium accumulated in these parts. The running of the old Maros bed more to the north is well supported by examinations of mineral compositions, from which it is clear that the results on samples taken near Lőkösháza and Apátfalva agree with those on present alluvial material originating from Deszk. The displacement of the Maros from its ancient valley to the present one was not a tectonic event, therefore, but the result of a surface development, filling-in that can be followed practically step by step. With the filling-in of the north-western sector of the talus, the main river was increasingly elevated and, slipping slowly in a southerly direction, migrated from its talus to newer and newer beds. With the occupation of its present bed, it left behind its side arms, which assumed a suspended condition and died out. The deserted beds were filled in generally with a fine sediment; with regard to the groundwater currents, these beds must also be taken into consideration as buried "subsurface rivers".

From the aspect of the groundwater course, the uppermost 4—6 m thick covering layers are the most important. In the talus system these consist mainly of infusion loess-covered mud, sandy mud and clay-containing facies of various thicknesses. These fine-grained surface accumulations have a very high specific surface and comprise an important factor in the water-household of the terrain by acting as water-impermeable layers. The slope and layer structure of this covering layer of the talus are of significance as regards the groundwater course, for the soil-physical properties of the covering layer are characterized here by the large capillary water elevation, which may mean a considerable magnitude of evaporation in dry summers. Since the specific surface of the granularity of the covering layer is relatively high, there may also be an appreciable running-off of the precipitation to deeper levels. In the course of field studies, it emerged that the amount of water evaporated is the more significant factor in the annual water balance, and hence the importance of the replacement of the prevailing groundwater must be sought in the more distant area. Not even the precipitation in the rainiest summer is able to make up for the considerable quantity of water reserve evaporated from the covering layer. Consequently, on certain areas of the talus the average level of the groundwater is relatively deep, but at the same time, in contradiction with this.

other areas were observed where the groundwater level is constantly high and exhibits insignificant fluctuations.

The talus of the ancient Maros below the covering layer is not of uniform structure in practice. With capricious meanderings in the course of its migrations, the river deposited a coarse-grained sand sediment in some places, and a finer-grained one in others. In the vicinity of the surface these spongy-structured sand deposits form lenses of various sizes, while elsewhere, following the bed-line of the ancient river in the direction of the Tisza valley, they result in sand strata. The lenticular-structured systems frequently form a continuous hydrodynamic unit, and thus a closed-system,

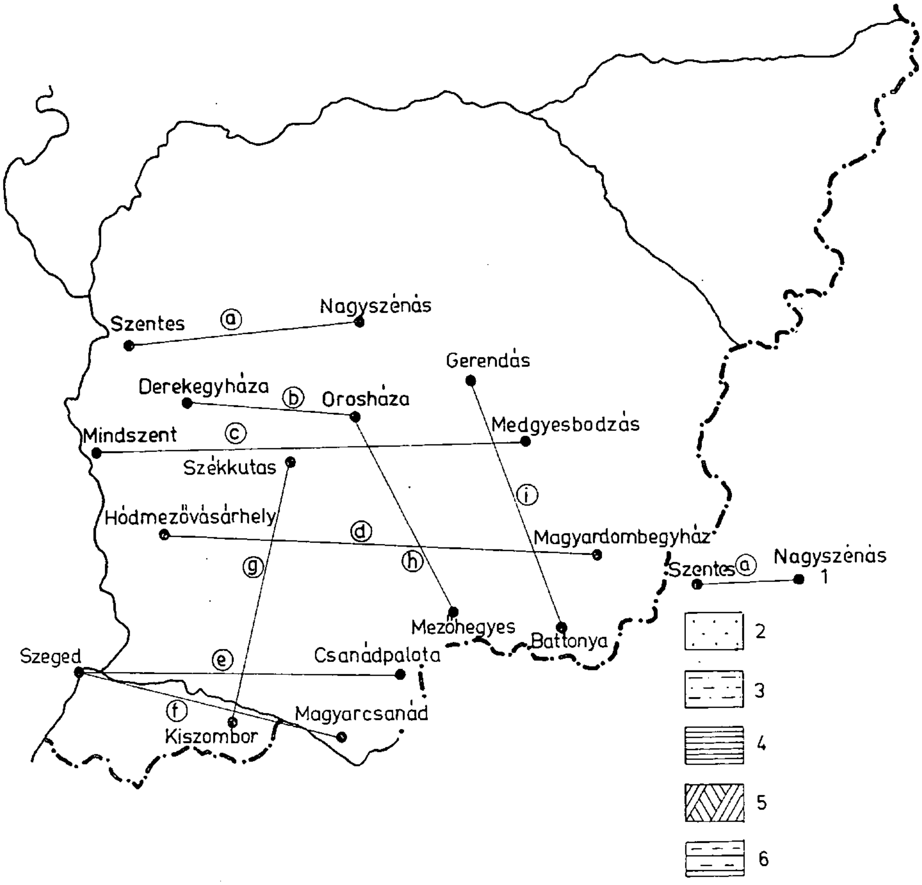
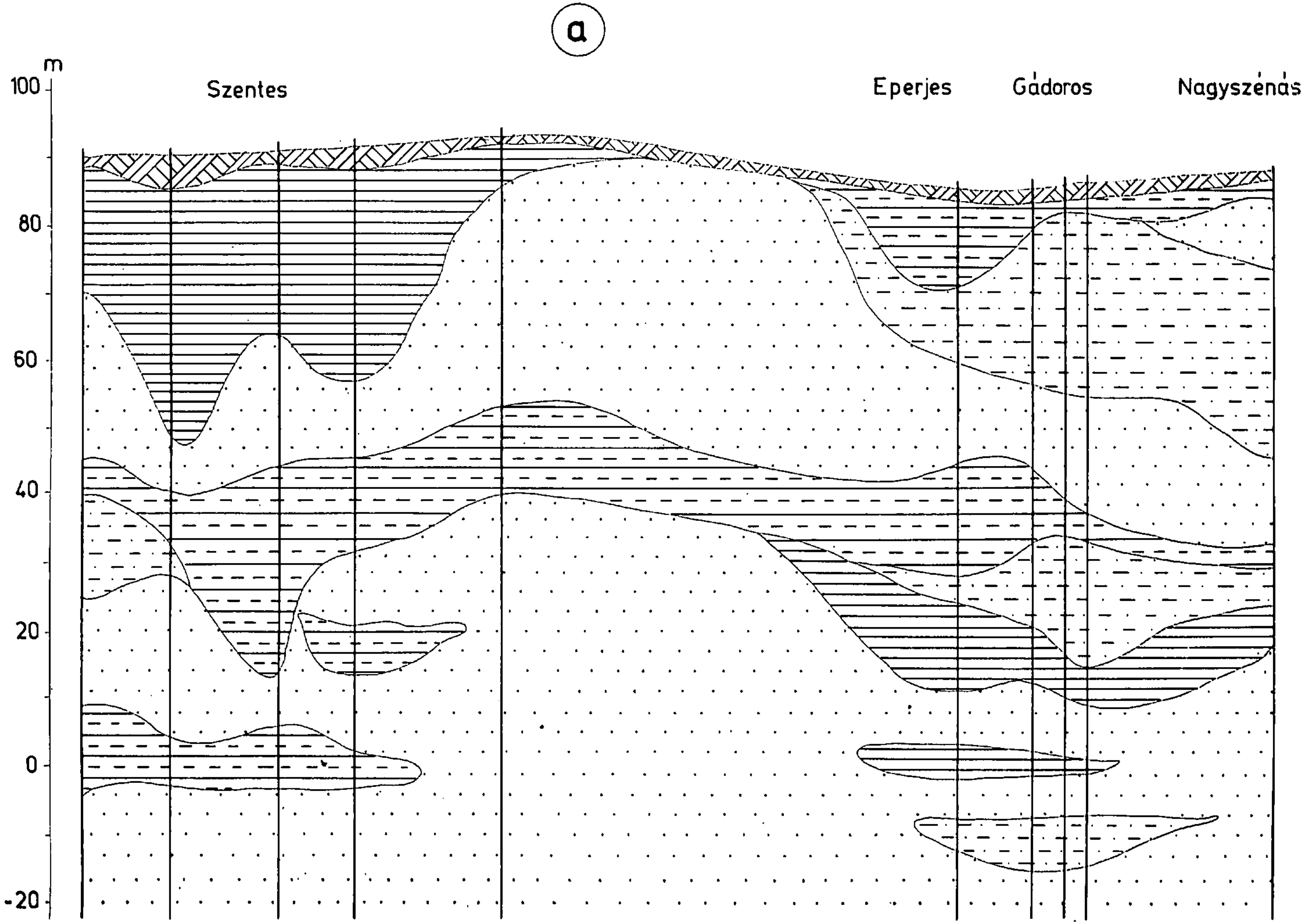


Fig. 3. Layer structure of the Maros talus area, and composition of the sediment. (Data of VITUKI.)
1. Directions and sites of layer sections.
2. Humous, loess-muddy surface.
3. Muddy, sandy-grained layers.
4. Sand layers with grains of various diameters.
5. Muddy, clayey-formation layers.
6. Clay layers



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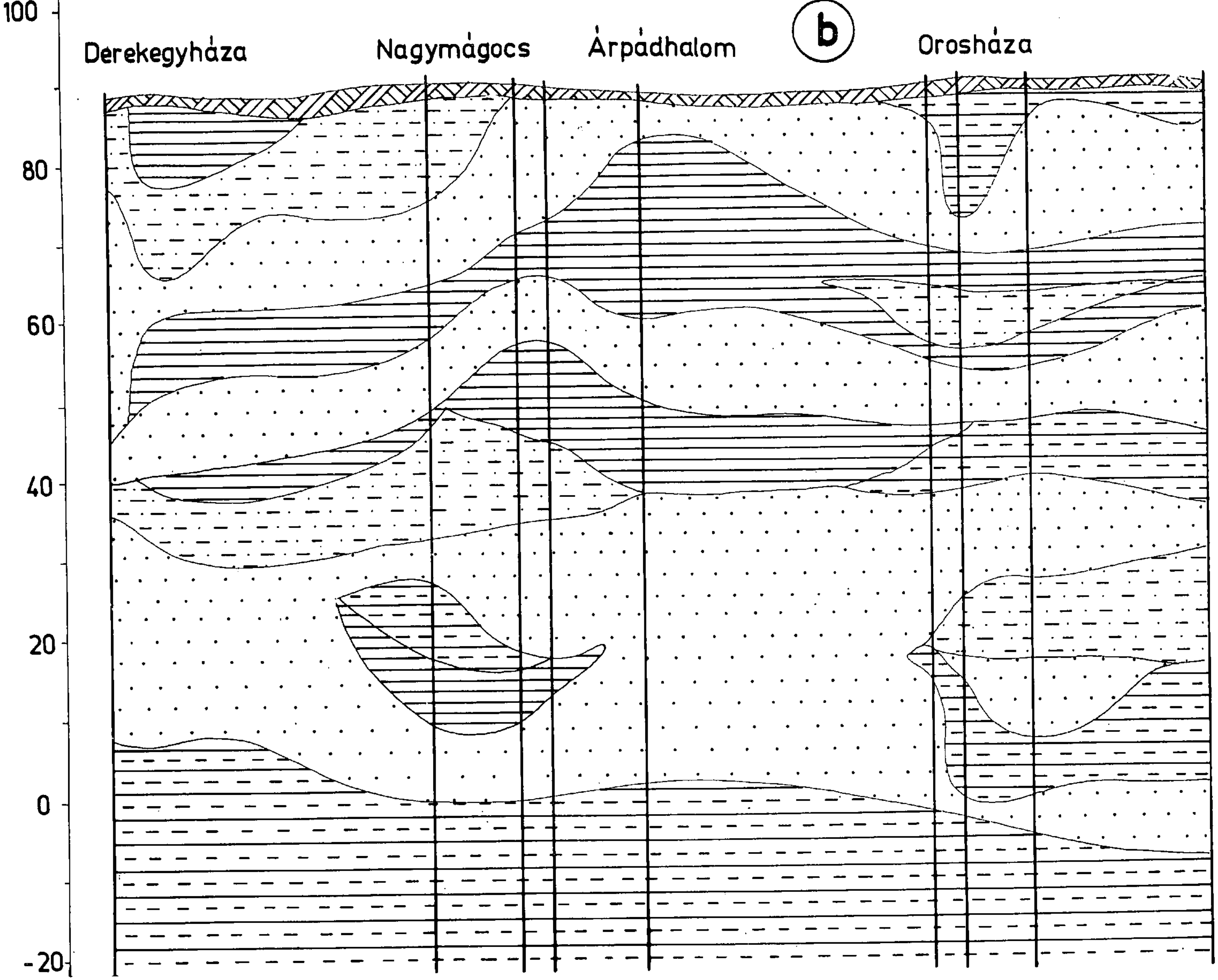
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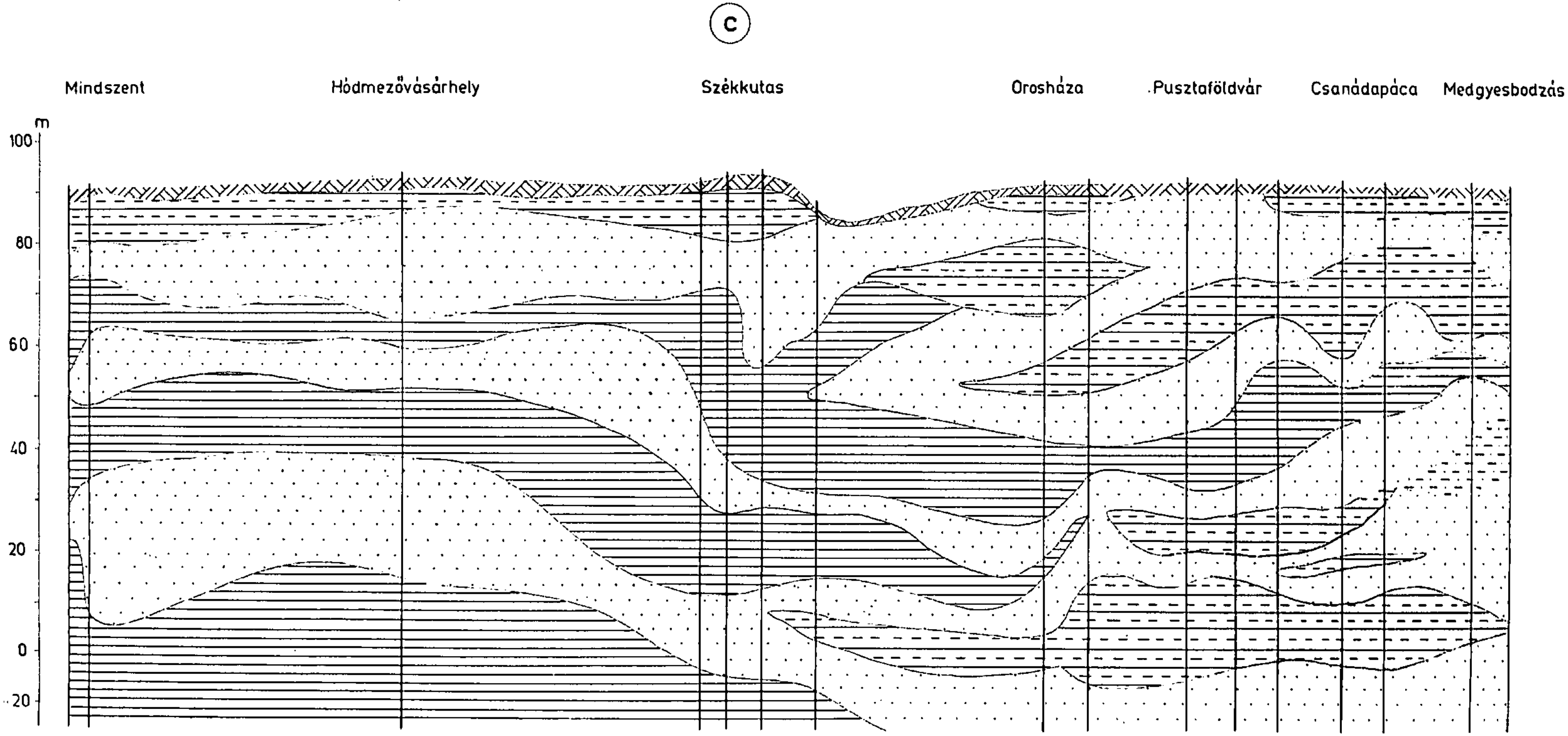
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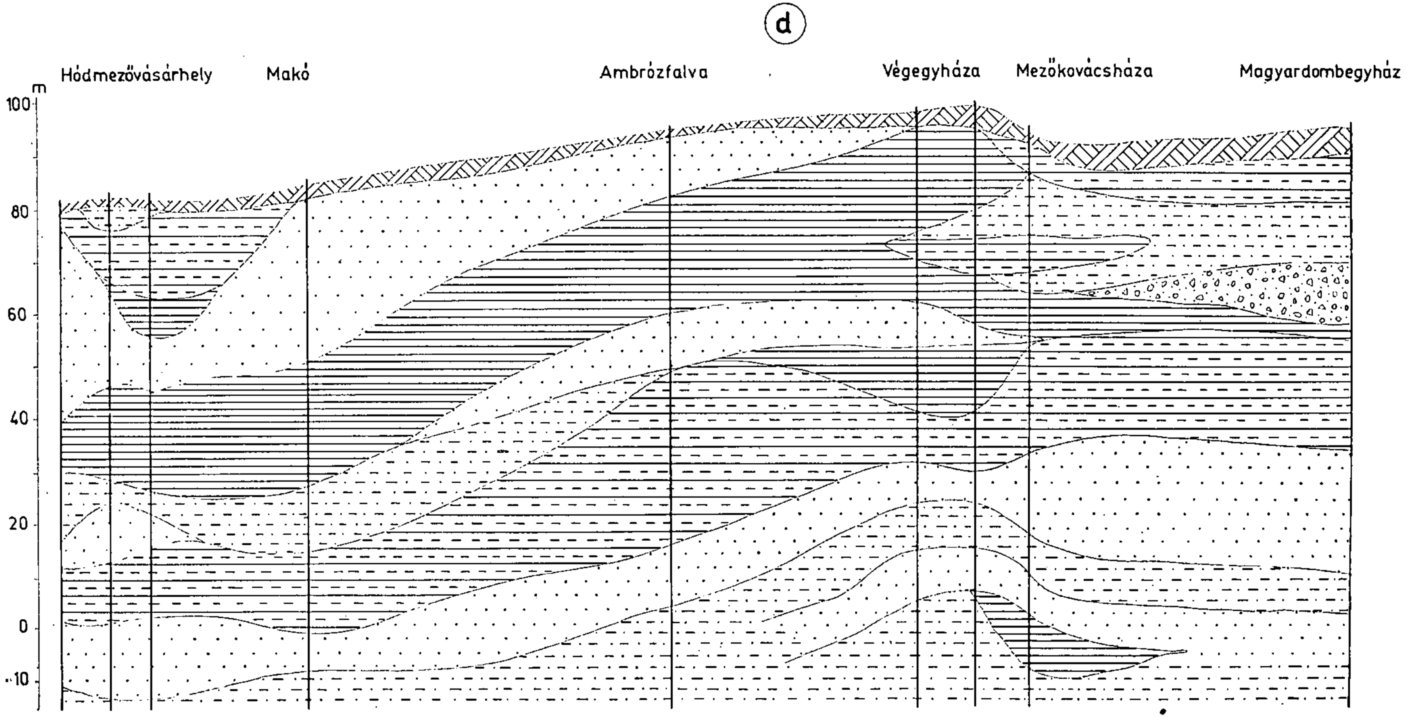
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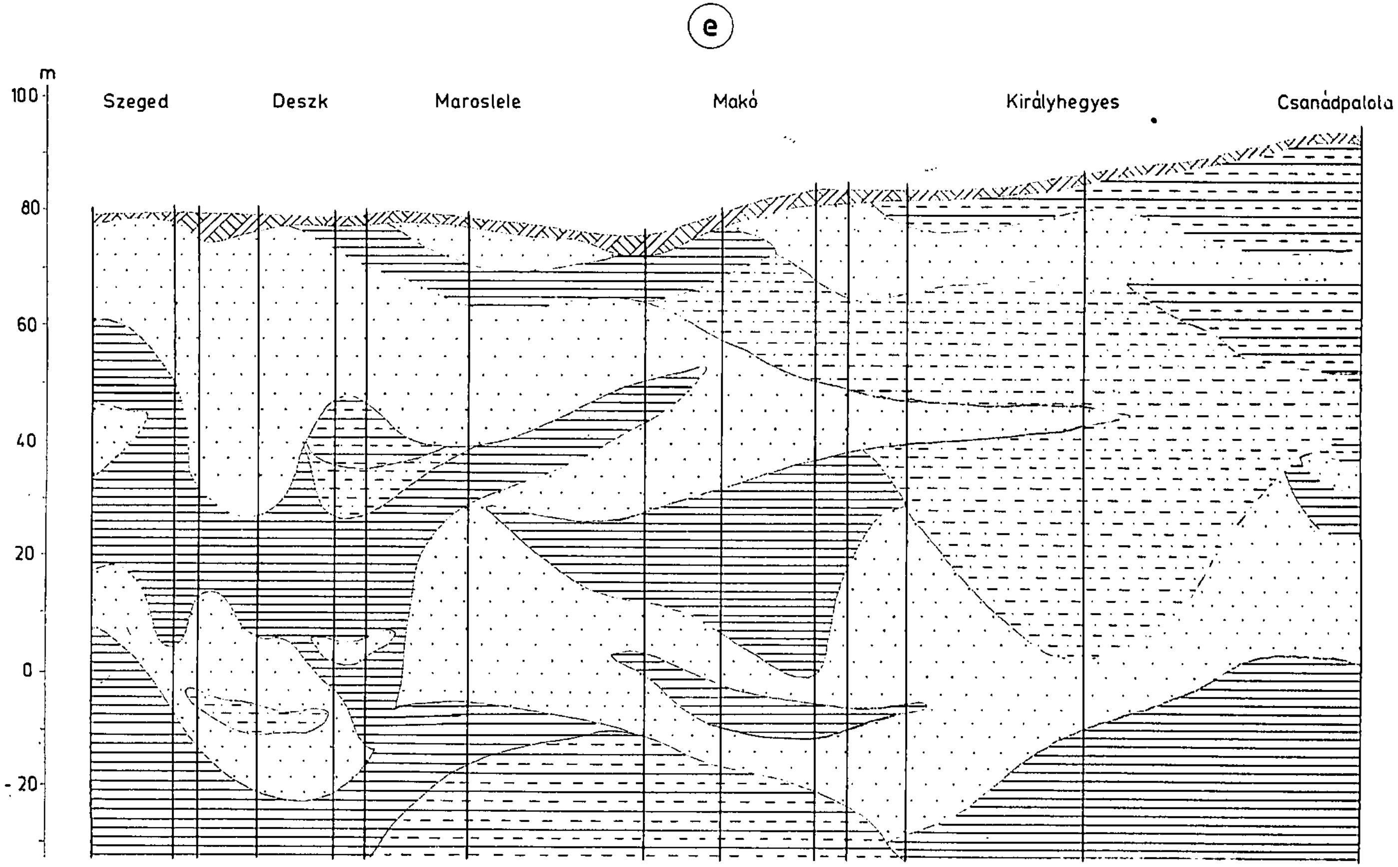
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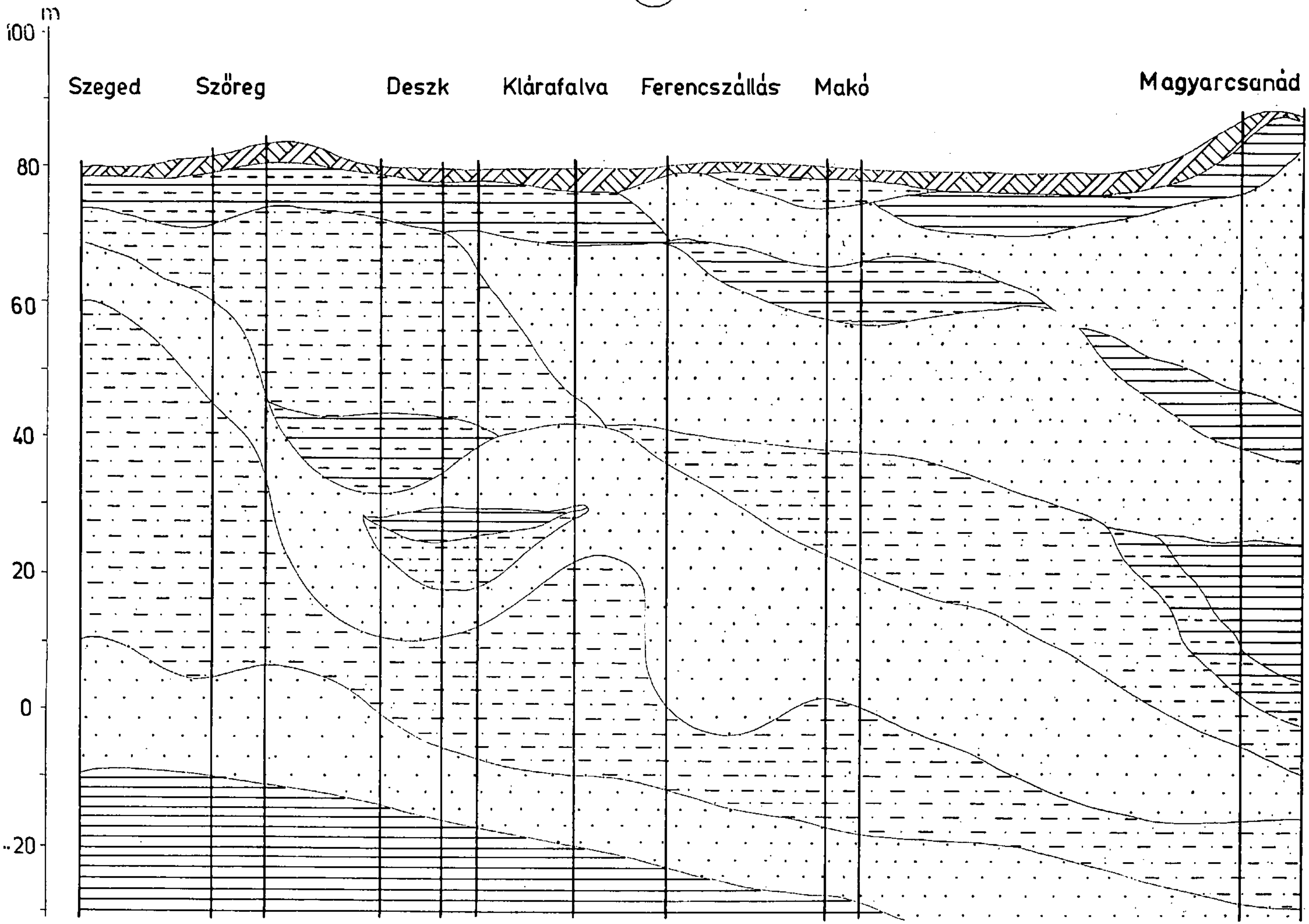
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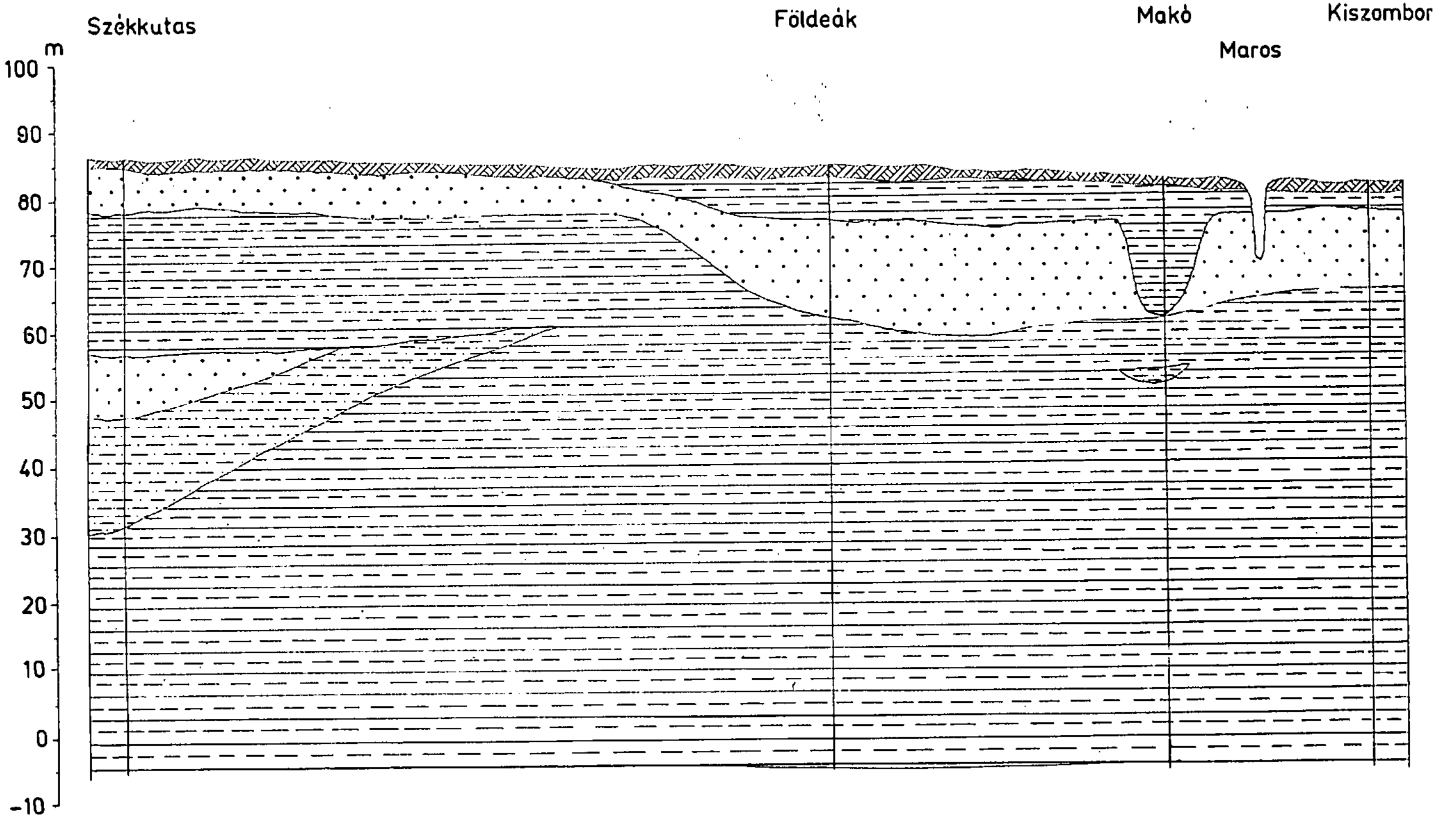
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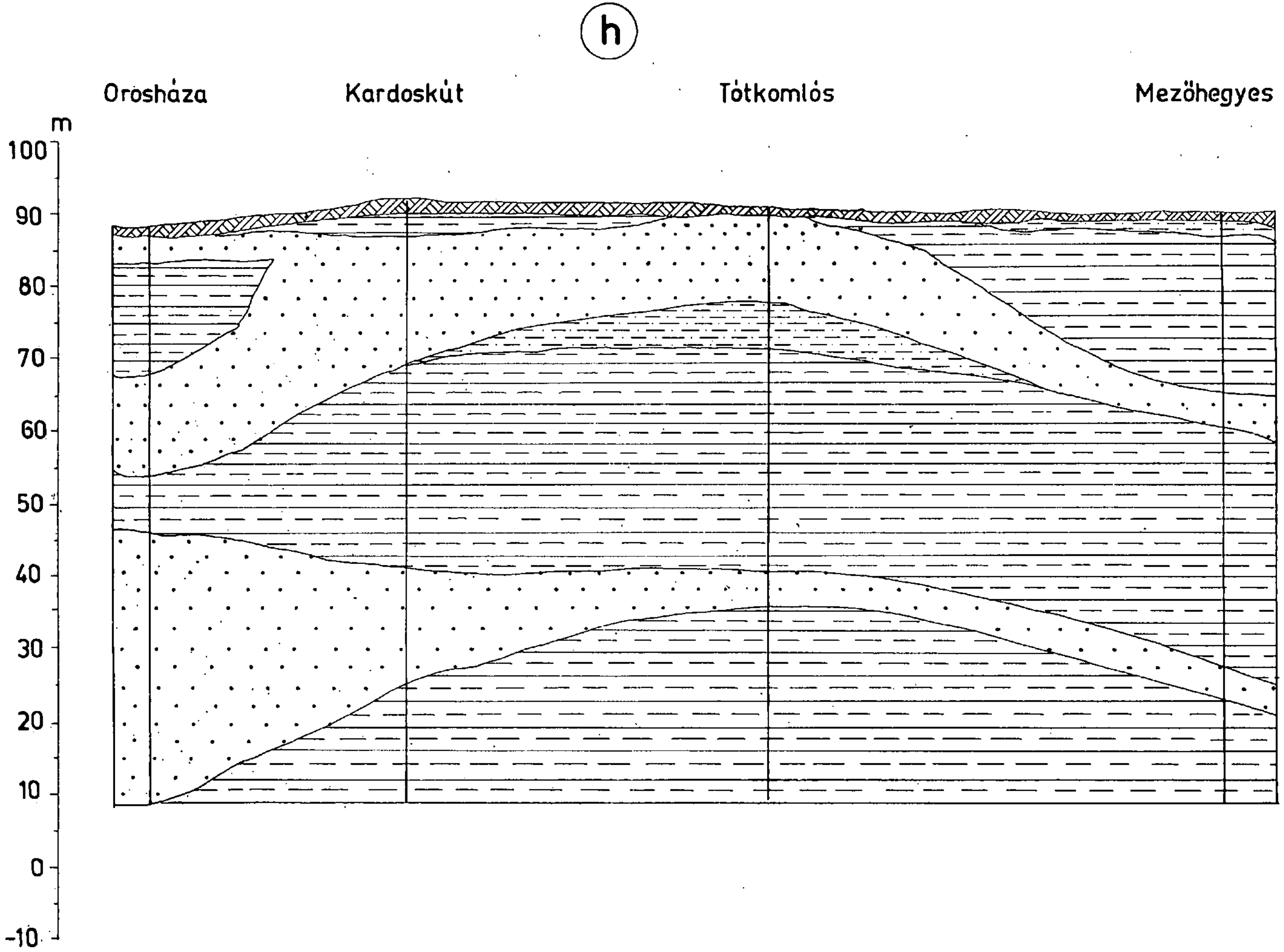
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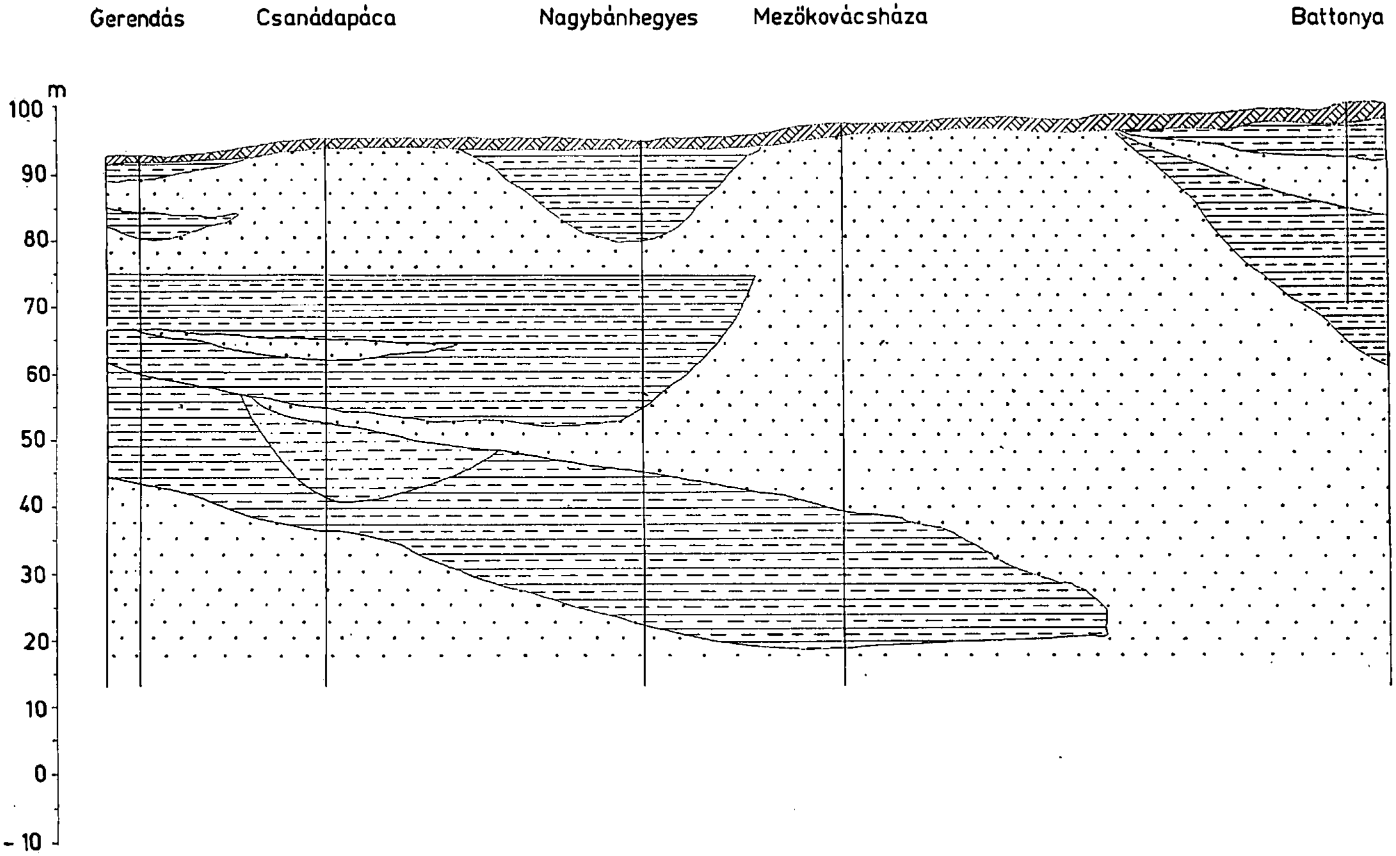
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water-impermeable layer structure close to the surface can be observed in only a few places in the talus (see Fig. 1).

The above-mentioned lenses were filled with water, and generally contain overpressure layer-water reserves. Since the weather of the Carpathian basin is strongly reflected in the movements of the subsurface groundwater of the terrain of the Great Hungarian Plain, the movement of the water in the water-impermeable layers is part of the water circulation occurring in the atmosphere, in the Earth's crust, and on the surface. This water circulation moves in the form of sepage, and additionally during the spreading of the shock waves in the elastic space and elastic material. The large masses of replacement water occurring on the higher seepage areas above the talus result in an increase of the effect, to a depth of several hundred metres, in the loose layers of the entire basin; in the area of the Maros talus this phenomenon may appear within a matter of days even (Fig. 4).

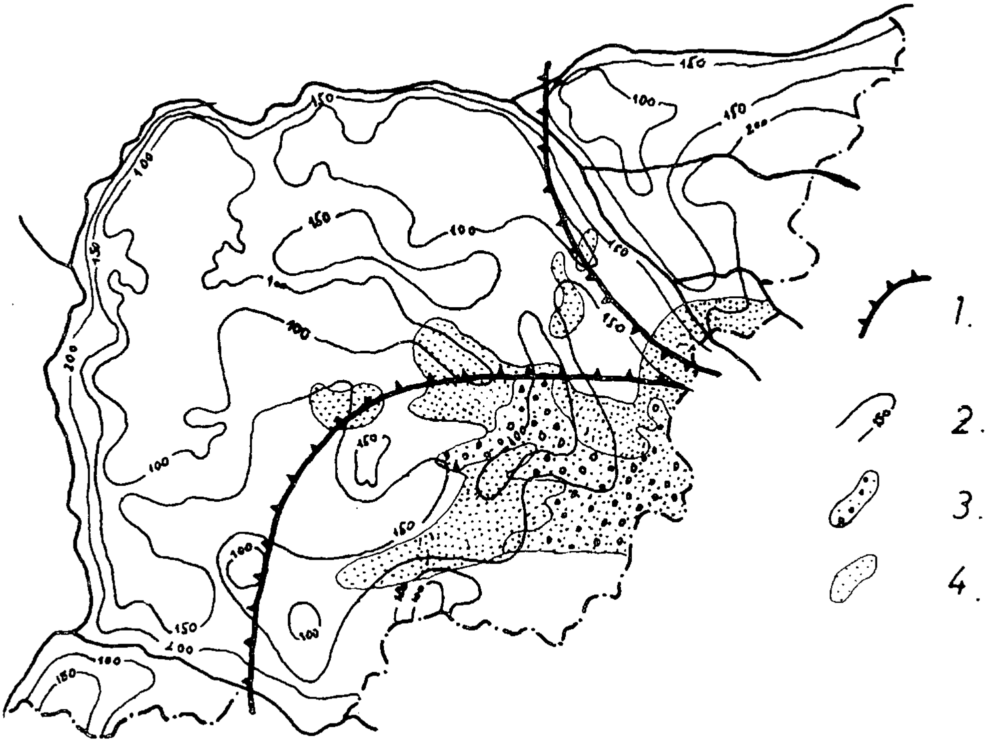

Fig. 4. Groundwater state of Maros talus. (Data of K. Ubell.)
1. Limit of deposition of gravelly layers protruding onto the Great Hungarian Plain.
2. Average water volume change in the zone of groundwater-level fluctuations, expressed in units of mm-sec. water-column height.
3. Area of groundwater turnover in a horizontal streaming with a magnitude of 5.0—3.0 l/sec/km².
4. Area of groundwater turnover in a horizontal streaming with a magnitude of 3.0—1.0 l/sec/km².

The regional, areal distribution of the layer pressure is strongly regulated by the geological conditions, and the free-surfaced water (groundwater) of the uppermost water-yielding layer is no exception. However, there are usually differing hydrological properties in the upper groundwater system, since the effect of the atmosphere is also manifested directly in situ (in the form of evaporation) in the water-bearing system near the surface. Areally, one can observe sediment structures with water-impermeable surfaces, as a result of which the groundwater too comes-under layer pressure. Ground springs (earth springs) may frequently appear in these groundwater regions in an overpressure condition.

As regards the change in level and the replacement of the groundwater, the direction and rate of movement of the groundwater are also of importance. If this takes place via seepage, then a phenomenon with a slower process is involved, as if it were replacement in an overpressure condition. In the former case it may be a matter of a streaming form of groundwater, which can also be recorded in the form of a wave, whereas in the case of overpressure layer states groundwater waves are not possible. In this area, therefore, as a consequence of the hydrological and morphological features the water is replaced primarily during the saturation of the available void volume. This may result in local essential differences areally. The internal stress produced by the saturation may increase due to the precipitation activity in the Maros talus and its mountainous system.

It was further observed that, in addition to the internal hydrogeological structure, the morphological characteristics too have a decisive influence on the developments in the water currents and water replacement. The groundwater level always has a surface nearly parallel with the ground-surface (Fig. 5). This dynamic equilibrium may generally be strongly affected by the evaporation; as the surface is approached, this increases in accordance with a square function. If the covering layer is not continuous and the evaporation is not able to maintain this equilibrium situation, surface waters and water levels appear at the given site. This phenomenon can generally be observed in the immediate vicinity of the mountain feet; at the same time, on other areas of the Great Hungarian Plain it is possible to find from time to time a groundwater level which fluctuates depending on the water-household conditions, but which is always nearly parallel with the surface.

As regards the covering structure and the precipitation factor, our investigations indicate that the surface precipitation does not even penetrate down to the groundwater level, at an average depth of 3—4 m. Accordingly, its vertical fluctuations are determined not by the extent of the local precipitation, but by the overall precipitation activity on other regional areas. In a summer with the highest precipitation in the Maros talus system, the surface precipitation is situated in a relatively transitional layer, which is used up completely in the transpiration of the plants. Thus, the utilization of the summer groundwater substantially exceeds the amount of water arriving in this manner, and the water balance of this area (on the Hungarian Plain terrains) is negative in summer. The local precipitation activity can therefore not be brought into direct connection with the prevailing groundwater level. The groundwater level and groundwater movement are the result primarily of the water replacement of the whole of the talus and of the outlying areas; as a consequence of the individual layer-structured characteristics, in this region this also appears in the form of an overpressure state. In these parts the effect of the precipitation activity shows up rapidly in the change of the groundwater level. At such sites a groundwater-

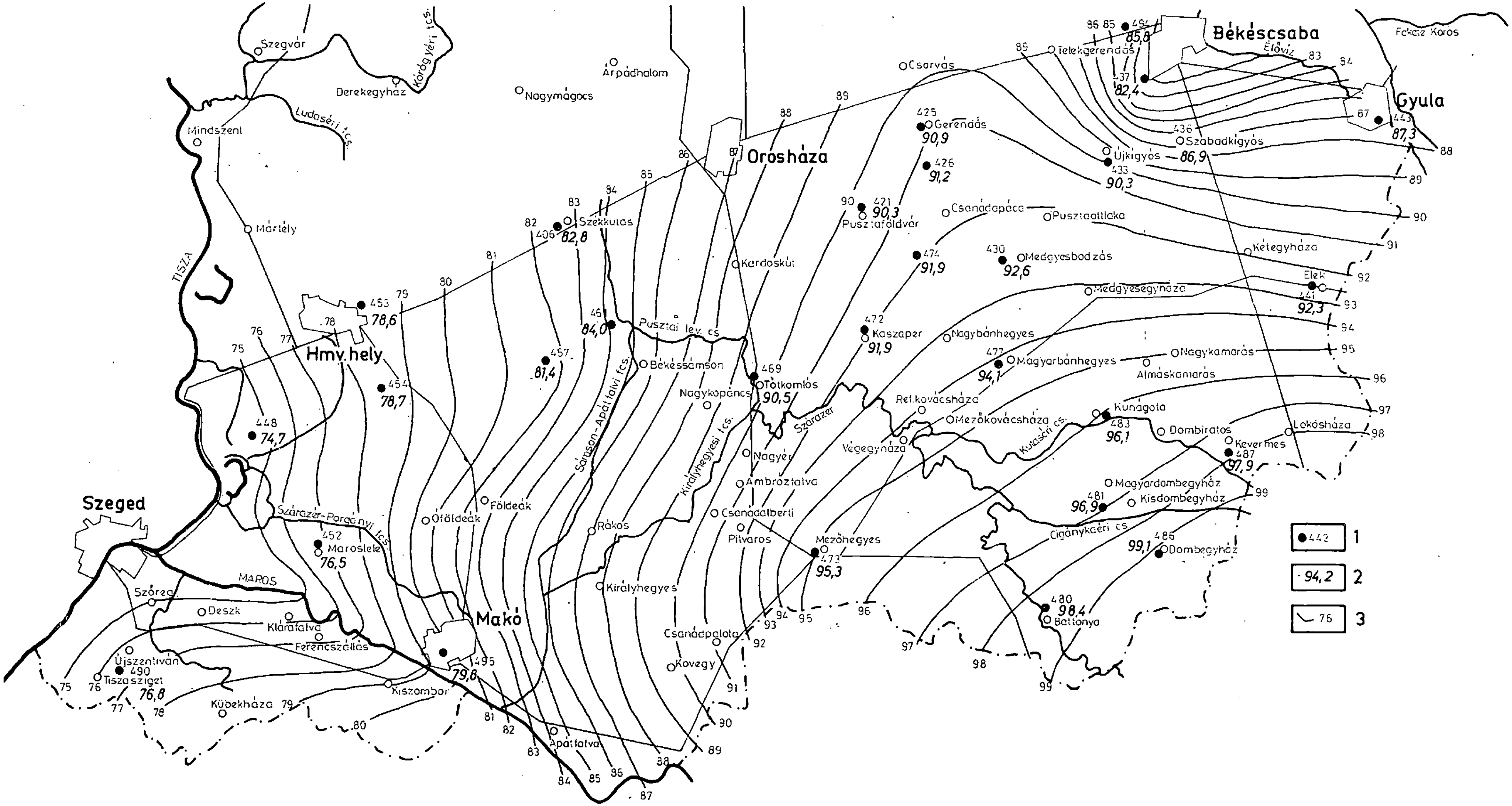

Fig. 5. Areal state of the annual mean-water condition of the groundwater level in the Maros talus. (Data of VITUKI.)
1. Sites and serial numbers of groundwater-observation wells of VITUKI.
2. Annual mean-water condition of groundwater, expressed in units of m above sea-level.
3. Values of the isohipse of the mean water level of the groundwater, expressed in units of m above sea-level.

level interval of even 2—4 m is not rare. A rapid filling occurs particularly in the water-level elevation stage, while the process of lowering of the water level is slower. In those parts where the hydrogeological structure does not ensure an overpressure condition, the groundwater level of the higher talus edges moves towards the lower talus areas by groundwater streaming under an atmospheric pressure effect. However, this process means a slow water replacement on the Hungarian Plain terrains. The calculations of certain authors suggest that only the uppermost layer of the groundwater participates in the water movement assumed to take place by streaming in the Maros talus, at a depth level of about 1 m.

Naturally, the water streaming does not proceed uniformly on the talus; it is faster in the directions of lower resistance, into the loose gravel beds. The water movement in such channels, both upwards and downwards, may differ from the average by an order of magnitude or even more. In the passages with higher permeabilities (on old river-bed lines), the changes in the precipitation seasons are quickly reflected in the variations of the groundwater level. The talus is extensively saturated with water if durably high water levels arise in the catchment areas of the Maros and the Kőrös, as a result of either intensive precipitation or snow-melting. The subsurface waters, however, do not appear primarily in those years when the rivers exhibit high water levels, but in the subsequent year or years. (For example, high groundwater levels occurred in the area of Békéscsanád following the prolonged high waters of the Maros in 1942 and 1971, in spite of the fact that the overall precipitation was lower than average in the periods of observation.)

The high groundwaters in dry periods also extend from the outlying mountains towards the Tisza, roughly in a south-east to north-west direction, in a floodwave manner. (For instance, there were groundwater spring-formations and higher than average groundwaters on the line Mezőkovácsháza—Mezőhegyes after the high and lasting flooding of the Maros in 1970, and on the line Hódmezővásárhely—Szentes in the spring of 1972. At the same time, the winter of 1971/1972 was precipitation and snow-free, and thus there was no question of local seepage.)

The observed phenomena prove that the groundwater course in the Maros talus system is influenced not by the local precipitation, but by long-range effects attributable to the water-catchment area. Saturation of the section of the talus on the Great Hungarian Plain with water is rapid and dynamic. Higher groundwaters must be reckoned with in the area even in those periods when the precipitation conditions of the area prove unfavourable for agriculture. At such time the groundwater reserves of the talus system ensure an appropriate amount of water for the provision of the lower arable soil levels with capillary water.

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