PHYSICAL-GEOGRAPHICAL AND GEOLOGICAL ASPECTS OF THE EXPLORATION OF THE HYDROCARBON RESERVES OF THE SOUTH HUNGARIAN PLAIN

L. JAKUCS

Our age has become a revolutionary period not only of technological, industrial and social development, but also of scientific development. Our changed and still changing and developing life forms, conditions and requirements mean that new types of social demands are expected of the natural sciences, which are so closely interwoven with our everyday existence. It is understandable, therefore, if the branches of science carrying out research into the various phenomenological groups of the objective world, the changes in these, and the causes of the changes (e.g. biology, chemistry, geology, physics or geography), are no longer satisfied with their earlier content, systematization and explanations, but achieve new society-centred aims by fulfilling the planning of the optimum degree of rational utilization of the natural environment by exploring the complex interactions between the phenomena. Thus, the new type of natural sciences wish to bring about the social control and direction of natural energy previously merely acting spontaneously or just lying dormant. In this way they are striving to help mankind to become a sage ruler of the world (in the noble sense) and a responsible director of events.

Many geological sciences are known to be attempting to achieve the understanding of the features of the landscape, the clarification of the development of the earth's surface, and hence to explore the natural reserves hidden under the surface. In addition to geology, geophysics, geokinetics, hydrology, pedology, etc, a very significant and ever increasing role must be played by natural geography, for instance in the exploration of the hydrocarbon and thermal water reserves. The reason why this is so is primarily that, as a consequence of its methodology and the essence of its scientific content, natural geography can create a unity of view and a broad complexity in the accumulated knowledge in the geological sciences, which can not always be achieved by the individual branches themselves, remaining within the frameworks of their own fields. In other words, this means that natural geography is the science that is able to take the geophysical, geological, geokinetic, hydrological, pedological, climatological, etc., part-results, and to view them in a constructive complexity and unified harmony, in which the various colours of the spectrum combine into a beam throwing light on new essential correlations.

In this paper, on the example of the area of South Hungary east of the River Tisza, I should like to demonstrate the extent to which natural geography in our age has assumed the stamp of modernity in the above sense, and the fact that it is no longer the old recording and descriptive discipline as many justifiably regarded it even only one or two decades ago. We have passed beyond the period of the preparation of large, descriptive, detailed geographical monographs. Our excellent predecessors prepared the detailed and supplementary geographical descriptions as reagards the regional aspects of the South Hungarian Plain, and they also explained (often amidst serious debates) the natural and anthropogenic processes resulting in the development of the present surface. Accordingly, therefore, it was necessary for us to proceed further and to seek the means of applying and utilizing the accumulated information. The earlier claim as to the revolution in geography is true only if a new classification of the available information and hence the perception of the resulting new correlations can be proved to serve practical interests, and if they truly assist in the exploration and utilization of the natural potentials.

In this concept of geography, the Department of Physical Geography of József Attila University in Szeged first attempted 10 years ago to prepare a dynamic geographical synthesis of the South Hungarian Plain from the aspect of raw material research. In the course of this large work, over the years we collected a vast mass of data, outstanding roles being played primarily by MIHÁLY ANDÓ and JÓZSEF FEHÉR; with the systematization and the overall evaluation (in close scientific cooperation with the OKGT, the National Mineral Oil and Gas Industry Trust) we wished mainly to provide information of assistance in the Hungarian hydrocarbon exploration.

Our work was made particularly significant by the fact that evaluation of the discoveries arising from the geological synthesis of the previous sporadically performed palaeogeographical investigations and hydrocarbon explorations had already provided initial encouraging results for the hydrocarbon research workers, while in addition the necessity of interscientific collaboration of a similar nature was definitely confirmed by the most recent Soviet hydrocarbon exploration experience, from an economic aspect too.

The preparatory, data-recording part of the work is documented by the presented maps. Of these, Maps 1, 2, 3, 4, 7, 8, 9, 10, 11, 12 and 13 are new and previously unpublished ones, specially prepared in our Department. At the same time, Maps 5, 6, 14, 15, 16, 17 and 18 have been taken from other sources without modification, or with only unessential modification (e.g. geology), for the sake of uniform and comparative evaluability. The maps taken from external sources (BENDEFY, DANK, Mrs. HAÁZ, URBANCSEK, etc.) were also transformed to a 1:100 000 scale and were provided with keys on a principle analogous to that of our own maps, in order to facilitate comparative examinations and measurements on them.

Before I present the essence of the dynamic physical-geographical regional analytic method, applied on a hydrocarbon basis in this case, by comparison of the meaning-contents of the 18 maps, I should like to say a few words separately about the individual maps; I should note that in the presentation I have relied strongly on the valuable results of the earlier work on research into the Hungarian Plain, primarily of my colleague MIHÁLY ANDÓ.

Map 1, a contour map of South Hungary east of the Tisza, shows the individual contours with level differences of 5 m. Within the region examined, a level difference of only about 30 m is found between the highest points above the Adriatic and the lowest points. The highest points are found in the vicinities of Kevermes and Battonya (108 m), while the lowest one is situated south of Szeged, in the southern section of the Tisza valley (78 m). The surface slopes uniformly downwards from the south-east towards the west; this is genetically connected with the fluviatile filling-up of the development and with the permanent subsidence of the

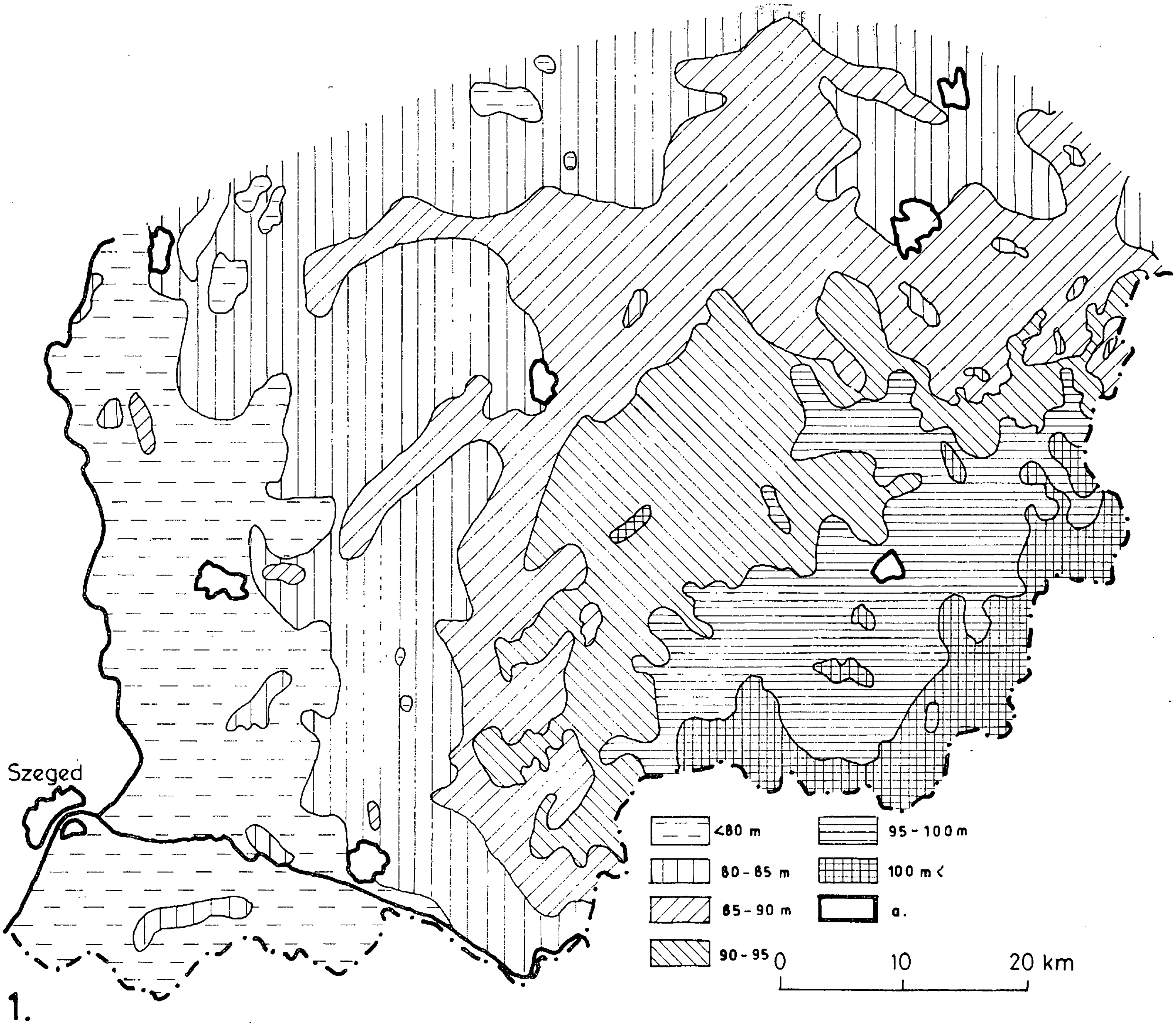

Fig. 1. Contour map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)
a = settlement

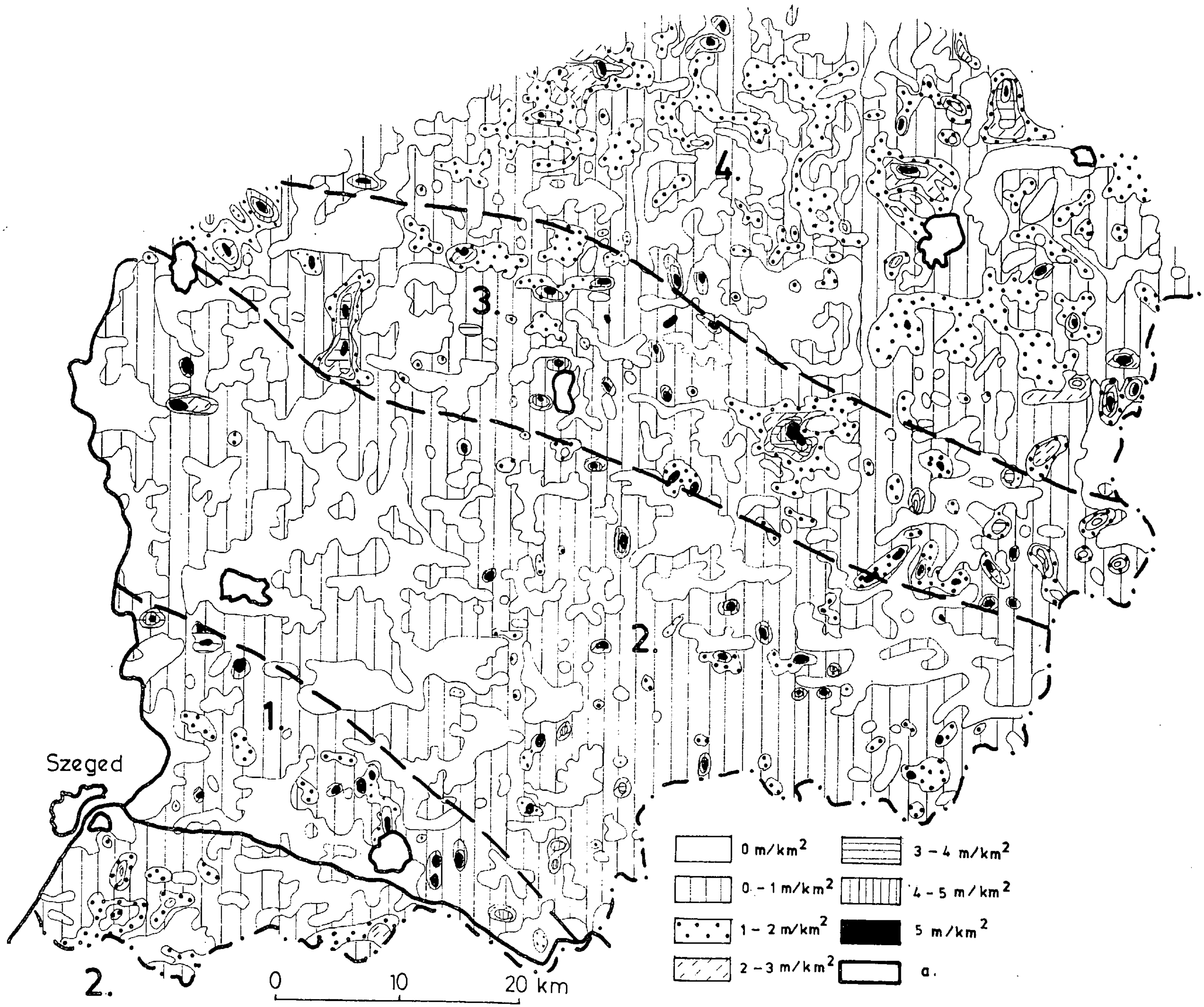

Fig. 2. Relief-Energy map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)
a = settlement

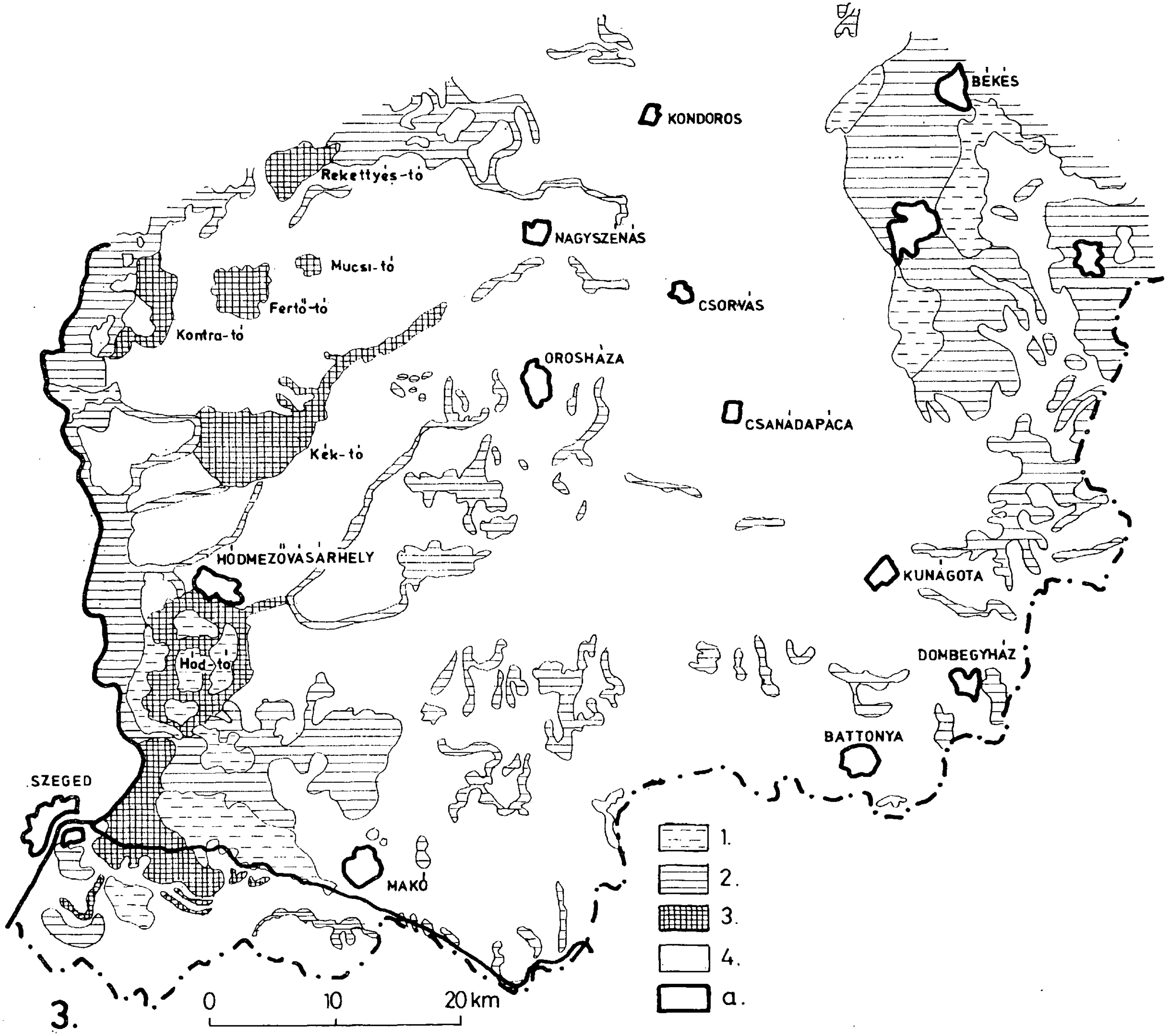

Fig. 3. Connate water map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)
1 = water coverage of flood plains and internal water
2 = water coverage lasting more than 6 months
3 = permanent water coverage
4 = dry terrain
5 = settlement

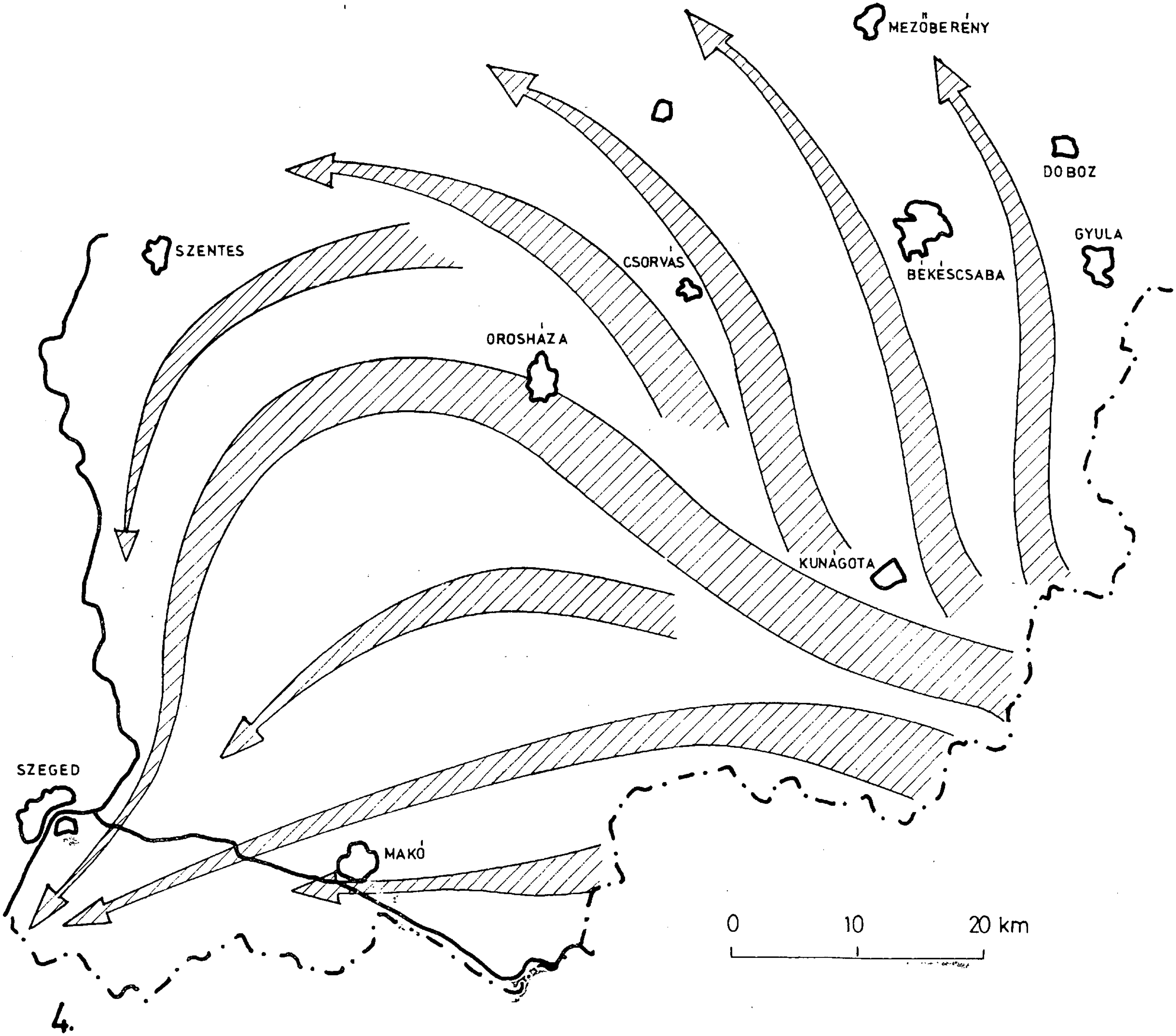

Fig. 4. Contemporary slope-tendency map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)

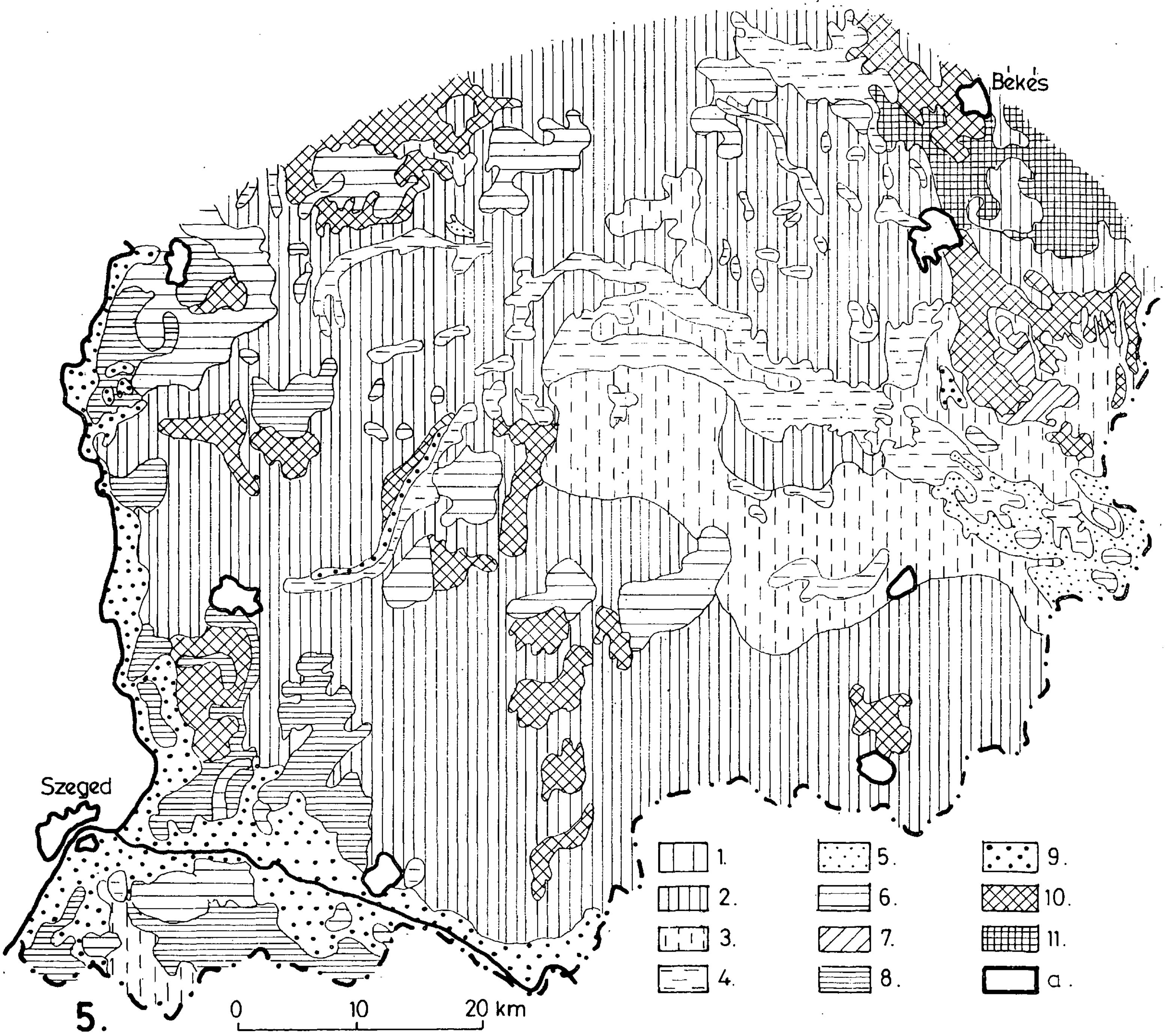

Fig. 5. Surface geological map of South Hungary East of the Tisza

1 = Typical loess
2 = Infusion loess
3 = Sandy loess
4 = Loessy sand
5 = Alluvial sand
6 = Clayey loess
} Upper Pleistocene

7 = Loessy mud
8 = Meadow clay
9 = Inundation sand
10 = Salinified alluvial sediment
11 = Brown earth
a = settlement
} Holocene

region. The smaller, more deeply-lying places compared to their environments (in the vicinities of Szabadkígyós, Orosháza, Csorvás and Nagyszénás), which are in contrast with the general east-west downwards-sloping tendency, are not indicative of the local subsidence of these areas, but are the consequences of the non-uniformity of the accumulation processes and of postgenetic factors (e.g. alkalinification, areal soil erosion, etc.). Depressions attributable to neotectonic processes in South Hungary east of the Tisza are expressed only in the form and terrain complexes of the larger regional units. Such areas with individual dynamics are signified by the subsidence area of the South Tisza valley with the Maros depression, for example, or by that of the Körös rivers, i.e. by the large depressions connected with the geokinetic processes on the western, northern and southern rim-lines of the region.

In connection with Map 2, a relief-energy map, it should be noted that the relief-energy values depicted are relative relief indices, prepared by regional interpolation of the relative level-difference indices shown at the centres of the square-kilometre network. The map reveals that, on the basis of the relief-energy types, there are 4 (comparatively well differentiable) regional units in South Hungary east of the Tisza. Proceeding from south-west to north-east, these are as follows:

1. The alluvium of the area of the influx of the Maros into the Tisza, where the relief energy is fairly variable, even in spite of the relatively level alluvial inundations. The outstanding values in this area are generally caused by positive forms, which genetically are mainly Pleistocene loess relict terrains. Even old oxbow lakes and abandoned bed sections too play a subordinate role in the areal determination of the relief-energy conditions. On 78% of this unit the relief value is 0—1 m/km^2, and only on 22% is it higher than this.

2. The zone with the lowest relief energy is a band defined by straight lines drawn between Szentes and Kevermes, and Algyő and Magyarcsanád, where the relief-energy values are 0—1 m/km^2 on 97% of the area. This zone otherwise coincides with the infusional surface of the western wing of the Maros talus, where the comparative lack of orographic forms means a reflection of the aeolian morphogenetics of the surface. The patches of small extent, but high relief energy, in the south-eastern half of the zone are caused partly by cairns, and partly by ancient river-bed and oxbow sections.

3. The morphologically most structured zone of South Hungary east of the Tisza is the band defined by the lines between Szentes and Kevermes and Nagyszénás and Elek, where the relief energy is lower than 1 m/km^2 on 76% of the area. At the same time, on the other patches the relatively high relief-energy values predominate, which are the projections of both positive and negative forms. This zone otherwise coincides with the rim-edge of the Maros talus, which is made more emphasized by the sand-band of the strata with a bank-side dune character, blown out and reaccumulated by the winds. There are also abandoned ancient river-bed sections between the sand-bands.

4. The richest band of South Hungary east of the Tisza as regards relief energy is the zone sloping down to the Körös depression, lying north-east of the line between Nagyszénás and Elek; in this, besides the surfaces with values of 0—1 m/km^2, which amount to 66%, the sites with higher relief energy also figure with relatively extensive arealities. For example, the surfaces with values of 1—2 m/km^2 comprise 26% of the entire area. This involves in part the isolated, aeolian-formed loesse, sand-dunes around Kondoros, and also the trenching lines dating from the end of

the Pleistocene and from the Old Holocene, which slope down to the Körös rivees. In the north-west half of the zone the lines of the Hajdúvölgy, Kórógy and Vekrr streams give negative forms showing up areally too.

To summarize, therefore, the relief-energy map may be evaluated so that the specific differences between the individual zone types are the consequences of the surface natural geographical processes which occurred during the Quaternary, and possibly anthropogenic effects, but not geokinetic reflections projeting out of the depths.

In connection with Map 3, showing the connate waters, it should be noted that it reflects the state prior to the river regulations and the prevention of flooding. In its construction, use was made not only of the cartographic material from the first military survey of *Emperor* JOSEF, but also of older cartographic material to be found in the archives. On the basis of the map of the connate water conditions, the area on the map can be subdivided into well-circumscribed details with characteristic zonal properties: 1. the north-south depression band of the Tisza valley; 2. the terrain of the western wing of the loess table in the South of Hungary east of the Tisza, divided by fluvial erosion and structured by smaller local depressions; 3. the floodwater-free table-land of the eastern wing of the loess table of South Hungary east of the Tisza; and 4. the depression area of the Körös rivers. The following remarks may be made in connection with the above-mentioned hydrographic regional units that can be well distinguished on the basis of the map of the connate waters:

The Tisza valley, which is becoming widely alluvialized in the southern part, at the mouth of the Maros valley, is undoubtedly conforming to the centre-line of a trough which at present too is subsiding more strongly than its environment; this is confirmed by the depressionally directed bed sections of the river valleys of the regional band adjacent to it to the east. Otherwise, the fact that even in the period before the regulation of the river, the sites with a constant water coverage did not coincide with the centrally situated flood-plain alluvium accompanying the direct channel-bed of the Tisza, but developed along a line almost parallel with the Tisza valley, 10—20 km to the east of it, is one of the dynamic natural geographical proofs of the Recent process of subsidence of the regional band. The streams with low erosional effects on the Hungarian Plain (Veker, Kórógy, Száraz, etc.) would have been unable to overdeepen their channels compared to their Tisza erosion base in continuous filling-up. In other words, this means that in the case of the constant water coverages in question, which appear to be overdeepened (Reketyés, Fertő-tó, Mucsi-tó. Kék-tó and Hód-tó), the fluvial overdeepening is only apparent; in actual fact, the process of subsidence of the terrain is reflected in those sections where the Tisza, accumulating much eluvium even on its flood plain prior to the regulations, could no longer equalize this with its continuous filling-up.

It must be noted that the reason why there is no water transport or water network on the floodwater-free table-land of the eastern wing of the loess table in South Hungary east of the Tisza, and also in the region of the "Hajdú stream table" around Kondoros, is that the area is situated relatively higher than its environment; further, because of its permeable near-surface rock facies, the lithological conditions of the development of the autochthonous water network too are unfavourable.

Finally, it should be noted that the floodwater affected area of the Körös

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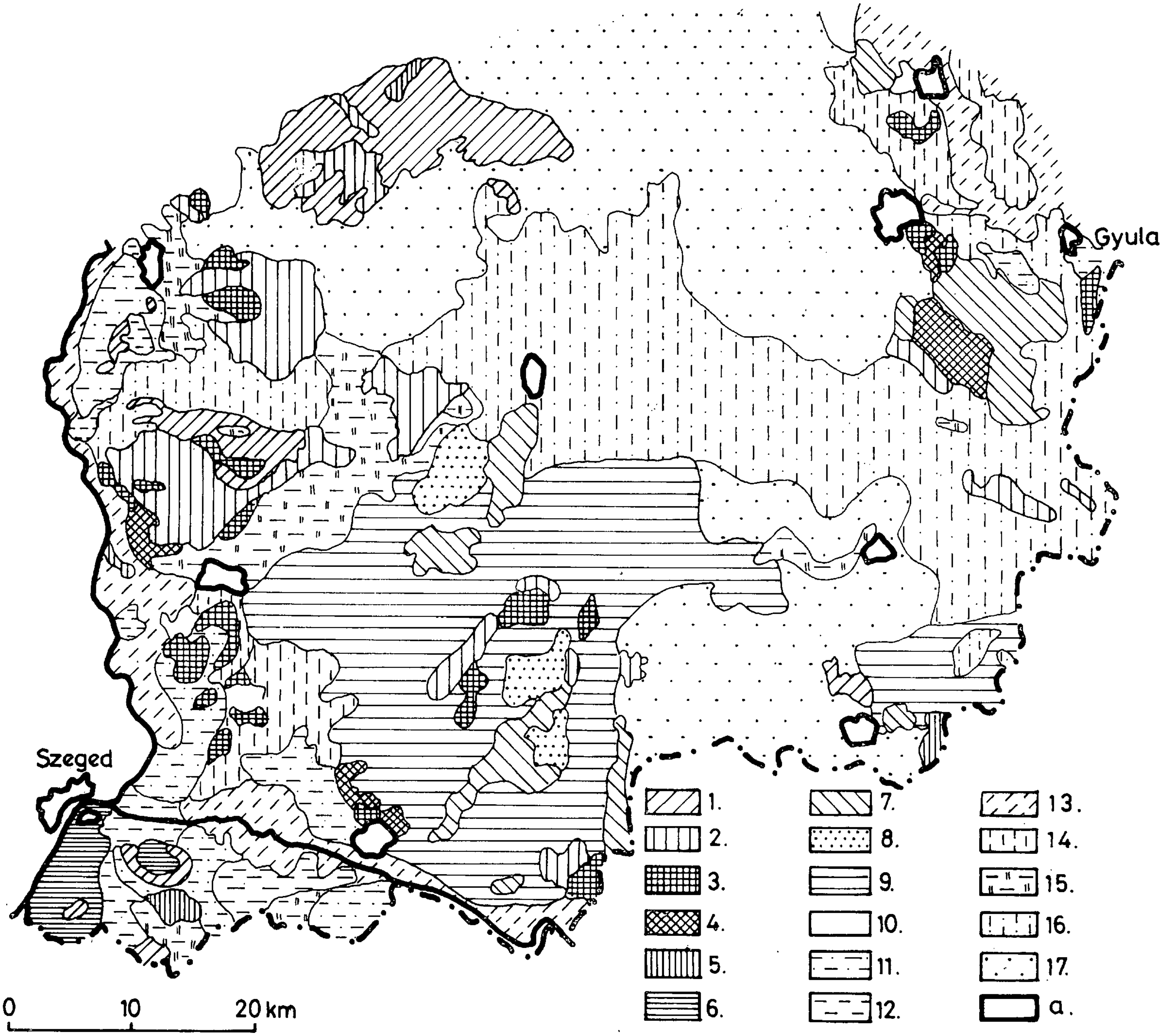

Fig. 6. Soil genetics map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)

1. Alkalinified sodic soil, deep solonetz
2. Grassland soil with sodic subsoil
3. Lime-poor sodic soil, solonetz
4. Limy sodic, solonchak sodic soil
5. Meadow soil with sodic subsoil, with humic inundation
6. Alkalinified deep sodic soil, with humic inundiation
7. Grassland soil with sodic subsoil, with lime-poor sodic soil
8. Lime-poor (Solonetz)+limy sodic (solonchak) mixture
9. Grassland soil with sodic subsoil, with moderately humus-layered soil
10. Alkalinified deep solonetz, alternating with humus layers of moderate thickness
11. Meadow soil with sodic subsoil
12. Humic inundation soil
13. Young inundation soil
14. Meadow soil
15. Grassland soil with thin humus layers
16. Grassland soil with moderate humus layers
17. Grassland soil with thick humus layers

a = settlement

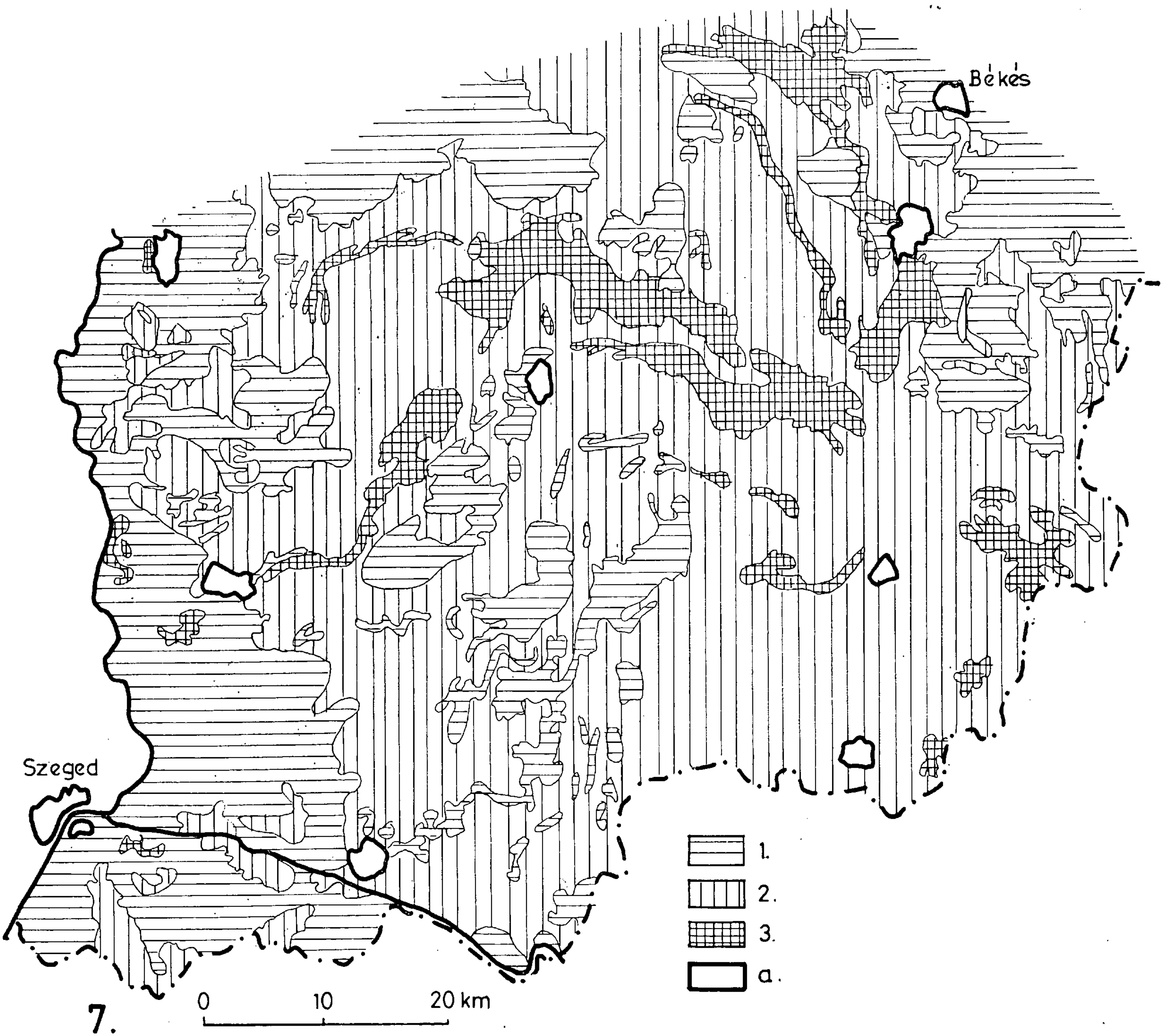

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Fig. 7. Permeability map of near-surface layers of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)
Sediments with
1good ($K=10^{-3}-10^{-4}$ 2=moderate ($K=10^{-4}-10^{-6}$ 3=poor ($K10^{-6}-10^{-8}$
water permeabilities
a=settlement

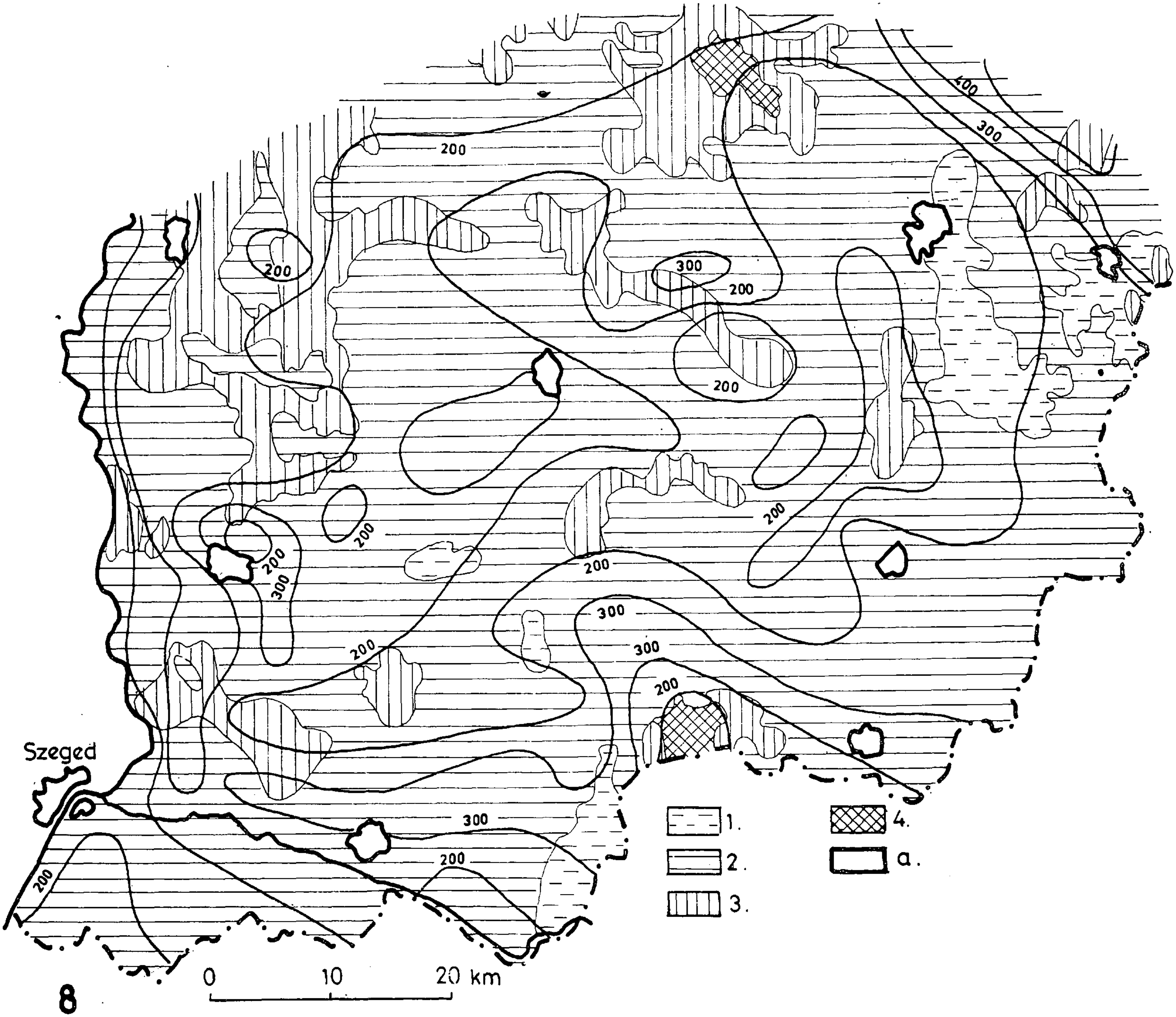

Fig. 8. Soilwater geograpiycal map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)
Average subsurface depth of soilwater:
1 = 0—200 cm   3 = 400—600 cm
2 = 200—400 cm   4 = more than 600 cm
The thick" lines and the related numbers indicate the differences in the extreme fluctuations oilwattr level inCM
a = settlemen

rivers, which before the regulations was one of the most characteristic swampy regions of the country (Sárrétek), could ascribe its inundation to the fact that the area strongly and permanently subsided. This geokinetic process was particularly intensive at the end of the Pleistocene and the beginning of the Holocene, so much so that the enormous Pleistocene talus of the Körös rivers was covered completely by a lymnetic and fluvial covering-layer formed in the Holocene.

Map 4, a map of the present slope tendencies of South Hungary east of the Tisza, is a dynamic natural geographical map constructed on the basis of the relief-energy conditions, the contour map, the connate-water map, the map of the Recent river-valley network, the density map of the specific water network, and measurements relating to the regional parameters of the specific water transport; its vector lines show the main ablation directions and the proportions of their orders of magnitude.

The map clearly documents that the main ablation centre of South Hungary east of the Tisza coincides with the centre of the ancient Maros talus situated in the environment of Battonya, Kunágota and Lökösháza; otherwise, this is expressed more intensively as reagards the talus character beyond the borders of the country. It may be stated that on about 60% of the area the natural ablation not yet disturbed by anthropogenic intervention, and the accumulation connected with this, conform to the centre line of the South Tisza as an erosion base; however, the lines do not always follow the direction of greatest sloping, but much rather the routes of the ancient river valleys, the positions of which were determined by the rim-line of the ancient Maros talus, and the gradual fan-like spreading of this to the west (cf. the course of the central, longest vector line, which displays a parallel with the running-line of the present Száraz stream, as with the most important channel system of the ancient Maros).

The dip in the southern direction of the ablational force lines otherwise similarly proves the intensive permanent tendency of the South Tisza valley (Szeged basin) to subside.

The complex dynamic ablational force lines that can be constructed in the north-eastern third of the region (about 40%) show the distribution of the acting depressions. The northerly running of the lines of the eastern rim area is undoubtedly explained by the depression of the Körös (Sárrét) subsidence region. In places this effect can be observed so markedly that, even in the absence of facies-identification drilling material, it must be assumed that in the course of the Pleistocene a mixing of matter onto the talus of the Körös rivers occurred from the direction of the ancient Maros talus too.

The declination to the west of the dynamic lines in the vicinity of the northern boundary of the region already expresses the effect of the Tisza of the Pleistocene. This depression might otherwise have been the erosion base of the running-direction of the ancient Ér, Berettyó and Körös too. In this respect the measurements confirm the known connate-water river-network development conception of JÓZSEF SÜMEGHY.

Map 5, showing the surface geology of South Hungary east of the Tisza, in our view faithfully reflects of our geodynamic findings generalizable to the history of the surface development, according to which the system of the Maros talus plays a decisive role as a central filling-up area, and the zone of the subsidence regions is situated along the northern and western rim-lines of this. In the central zone the rocks are generally characterized by a higher porosity (this is the case for both the fluvial and aeolian sediments), whereas in the subsiding troughs of the rim parts, which at present too are accumulational areas in the main, the finer-compositined and structurally too more compact lymnetic and fluvial sediment facies predominate.

In Map 6, a soil-genetics map of South Hungary east of the Tisza, we finu three soil regions in a genetic sense. Although two of these (the Tisza valley and the Körös region) resemble each other in many respects as far as their soil genetics are concerned, from a geographical aspect there is nevertheless an essential difference between them because of the predominance of the lymnetic or the fluviatile character. The third area (the table-land of the Békés-Csanádi loess table) has different soil features from the foregoing, being characterized by the soil varieties formed on the more porous rocks.

The soils of the Körös region primarily developed from sediments washed in from the environmental higher areas as a consequence of the close interaction of the flowing and standing waters. Extensive clay surfaces formed, which develop to have very different thicknesses and qualities in the course of the water-coverage of the terrain to various depths. In the depressions clay was generally deposited, the mother rock of which was mainly loess and red clay. The difference between thes two mother rocks is also expressed in the present soil characteristics.

In the Körös region, in addition to the clay there is also a significant occurrence of inundation soils, particularly in those parts where the rivers accumulated sediment series by continual repetition, without a longer interruption, in the meantime no swampy vegetation developing in the area. In contrast, in those places where swampy vegetation too developed, the most bound black meadow clay soil is found.

The soil conditions of the valleys of the Tisza and Maros exhibit a close connection with those of the Körös region. The correlation is particularly expressed in the fact that here too the soils are of young origin, and these developed primarily as a result of the running and standing waters. There is a difference, however, in that there is less red clay and more inundation mud in the soil-forming sediments, and because of this the soils produced here are not so bound as in the previous region. The individual types are situated regularly, parallel with the current channel of the Tisza. Thus, young inundation soils may be seen in the immediate vicinity of the river, with meadow and meadow-inundation soils farther away. In the case of these latter two soil types, clayley binding too is frequent. These soils are acidic, which is indicative of a Tisza origin.

On the Békés—Csanádi loess table-land the arable soil layer developed in the main from Pleistocene sediments (infusion loess, sandy loess, muddy loess, sand, etc.). In places, soils formed on alluvial flood plain sediments also occur, but these are restricted only to the regions of the old ox-bows.

The construction of Map 7, showing the permeability of the near-surface layers (0—10 m) of South Hungary east of the Tisza, was considered important, for in our view the nature of the region-constructing processes is reflected better and more faithfully by the petrological character of the 10 m thick near-surface complex of layers than by two-dimensional geological or pedological maps depicting merely the surface conditions. In addition, such a map is indispensable for a genetic assessment of the hydrogeographic, and particularly of the soilwater-geographic, characteristics. Our map was constructed via the processing of the material of near-surface drillings by VITUKI.

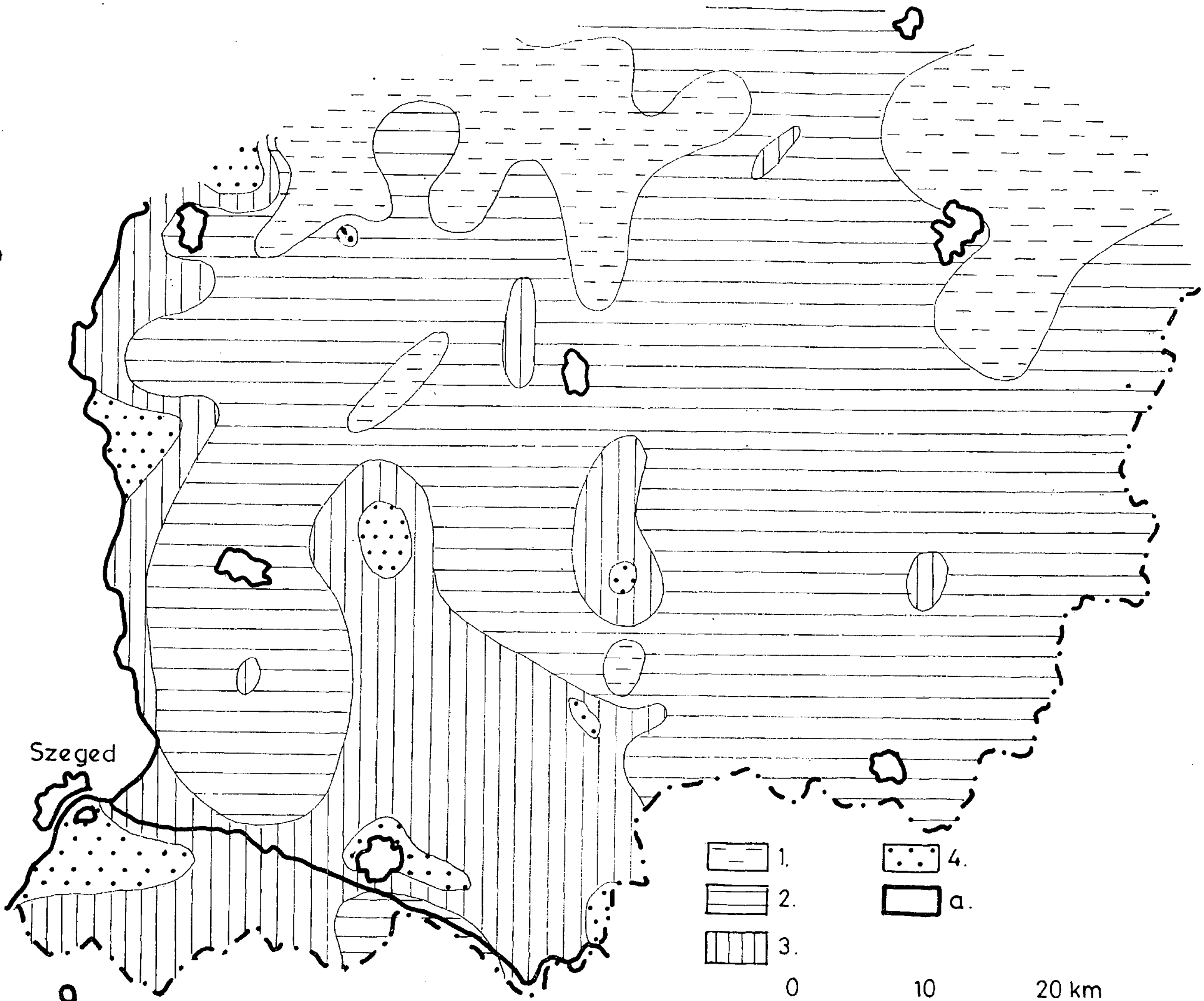

Fig. 9. Percentage sand contents of the sediments of the 200—300 m strata in South Hungary East of the Tisza (Prepared in Dept. of Physical Geography, Attila József University, Szeged)
Percentage of sand in the 200—300 m stratum:
1 = 0—25% 3 = 50— 75%
2 = 25—50% 4 = 75—100%
a = settlement

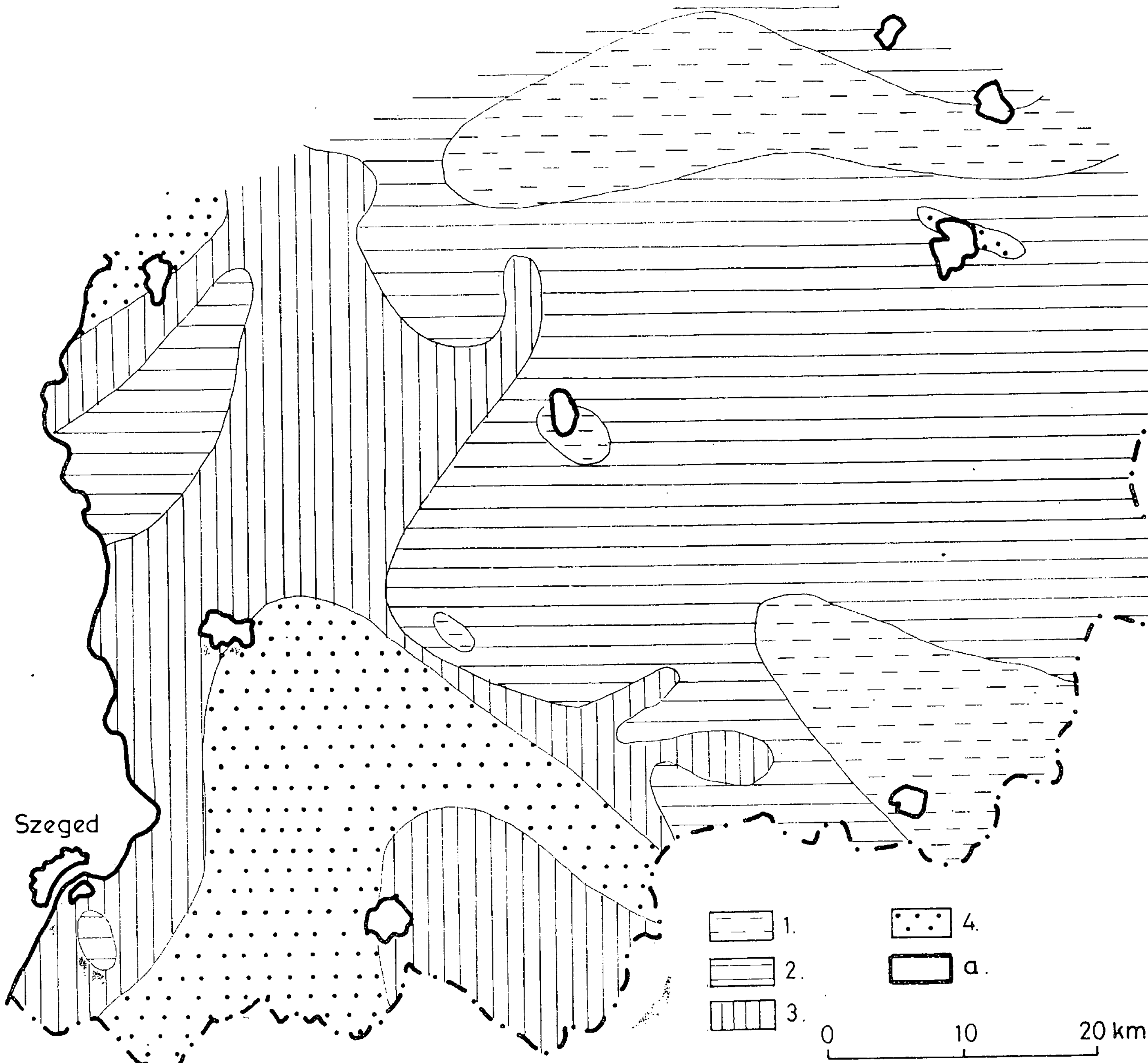

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Fig. 10. Percentage sand contents of the sediments of the 300—400 m strata in South Hungary East of the Tisza (Prepared in the Dept. of Physical Geography, Attila József University, Szeged)
Percentage of sand in the 300— 400 m stratum:
1 = 0—25„ 3 = 50— 75%
2 = 25—50% 4 = 75—100%
a = settlement

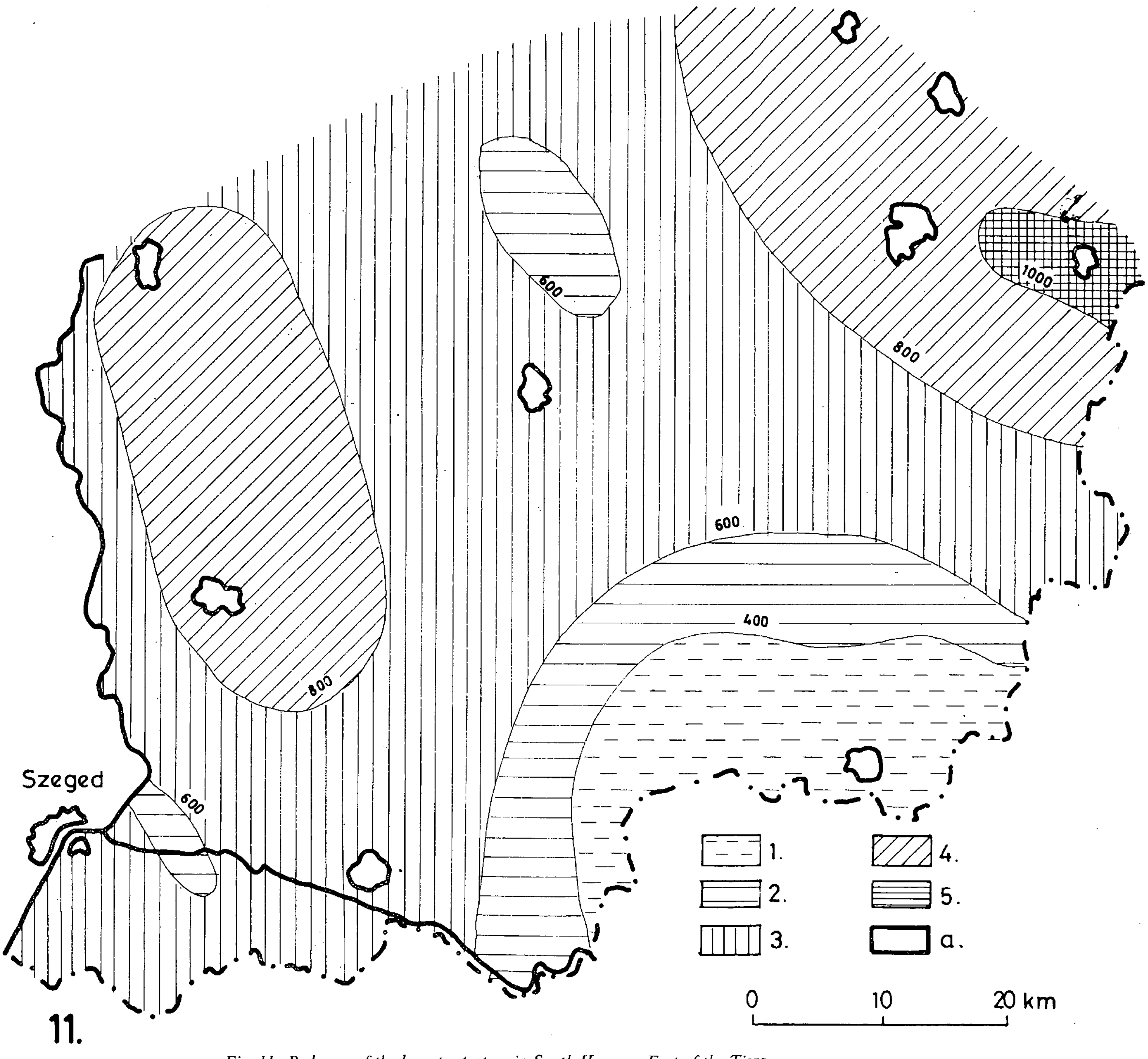

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Fig. 11. Bed-map of the levante stratum in South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Ettila József University, Szeged)
Depth of the Levante bed compared to the levele of the Adriatic sea:
1 = 400 m, 4 = 800—1000 m,
2 = 400—600 m, 5 = 1000 m
3 = 600—800 m, a = settlement

Analysis and comparative evaluation of the drillings and the grain-size curves led to the finding that the frequency of the sandier, coarser-grained compositions displays a linear correlation with the height of the area above sea-level. However, this correlation is manifested only statistically, for sandy facies occur in lower situations too, though these generally exhibit linear development and finer fractions.

Naturally, attention must also be paid to the circumstance that whereas the regions with a definite height above sea-level have a large areal extent, the frequency of occurrence of the sandy layer composition associated with these remains linear and is materialized only with linear statistics. This circumstance proves, therefore, that a faithful picture of the individual phases of the course of palaeographic development may be obtained only by means of a combined evaluation of the drillings and the related surface-morphological investigations.

As regards Map 8, depicting the soilwater geography of South Hungary east of the Tisza, it must be noted that this is based fundamentally on the soilwater map of KÁROLY UBELL; supplentation of this was made on the basis of the observation data of our Department, and also those of the VITUKI station-network, which were all subjected to statistical processing.

The most striking characteristic of this map is that the boundaries of the rest levels of the soilwater (denoted by dots) differ considerably from the field-boundaries of the water-level fluctuations (denoted by lines); this is a consequence of the permeability and conductivity of the near-surface layers, the flow direction and flow rate tendencies (which depend on the various soilwater level heights), and the morphological features. It is interesting to note the lateral deflection of the soilwater fluctuation contours in the region of Tótkomlós; this is related with the areality of the sand layers built up in the Maros talus, and with the abundant soilwater replacement from the direction of the Erdélyi island hills.

Map 9 gives an interpolated cartographic plotting of the percentage sand contents of the sediments of the stratum at a depth of 200—300 m. For its preparation we made use of the drilling records and descriptions of strata connected with artesian wells with a depth of at least 300 m to be found in the documentation of the Hydrological Department of the National Water Board and also in the national register of wells. These data were supplemented with the values obtained from the electrical survey profiles of hydrocarbon prospecting drillings made available by the OKGT. With regard to their sand contents, the following descriptions were applied to the various types of sediments:

sand, gravelly sand	100%
muddy sand	75%
clayey sand	60%
sandy mud	20%
sandy clay	10%
mud, muddy clay, clay	0%

It should be noted that the geological age differences were not taken into account in the construction of the map. These age boundaries have not been sufficiently well clarified in the transverse layers, while in addition the primary aim in the preparation of the map was the elucidation of the vertical movement tendencies of the area in question, which may be better reflected in the facies-differences of the sediments according to grain size than according to the geological age boundaries.

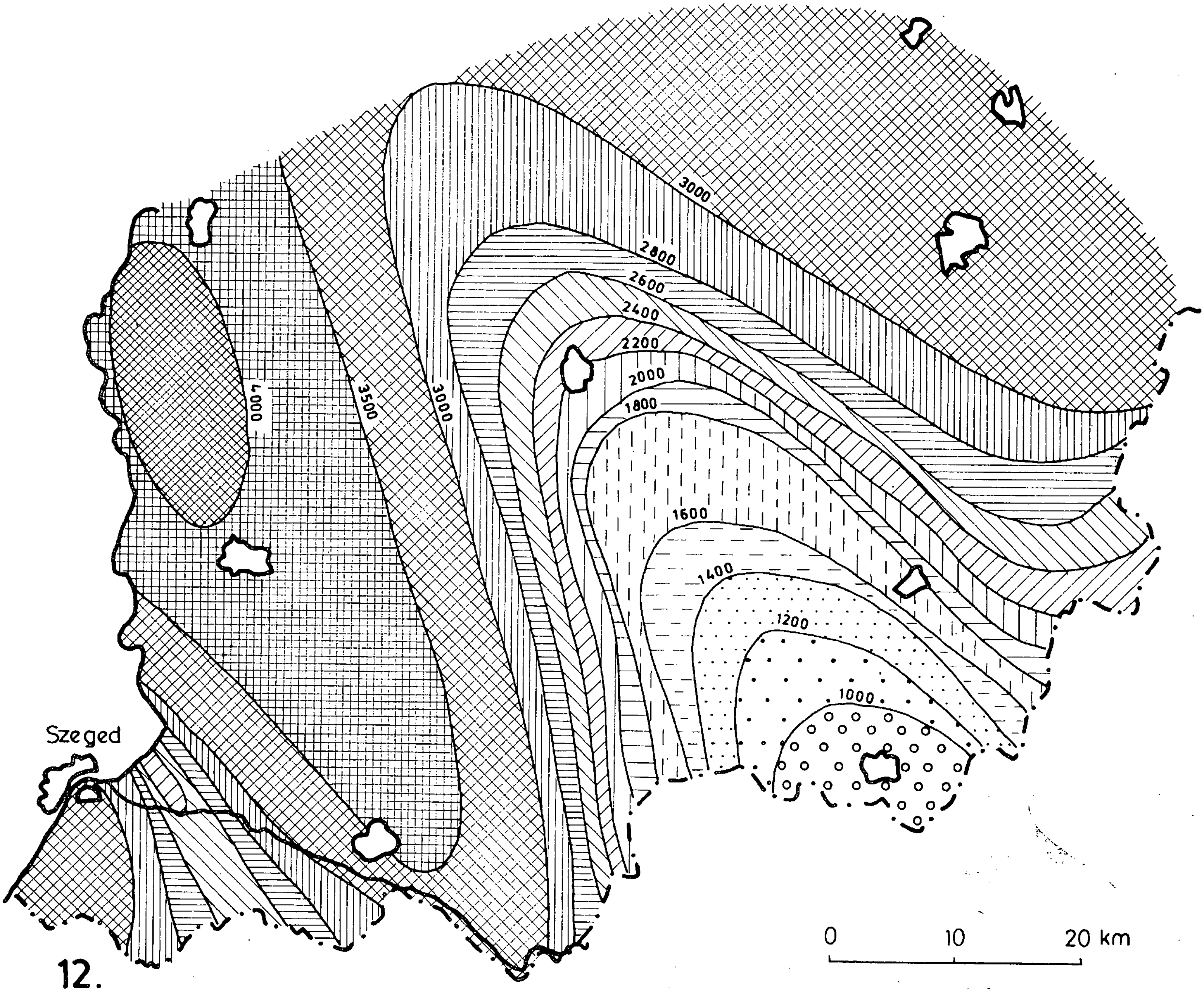
The map illustrates well that the coarser-grained sediments are situated in the western and south-western parts of the area, while the sediments have finer grains in the north and east. This can be explained in that Pleistocene deposits of fluvial origin appear in the western half of the stratum examined, whereas in the eastern half of the area we are concerned with finer-grained sediments of lacustrine origin from the end of the Tertiary. At the same time, however, this circumstance may also indicate that the main line of the present Tisza valley and particularly the district where the Naros joins the Tisza was the most strongly subsiding part of this area, even when the sediments in question accumulated.

It may be established from the map that the Maros talus, which is sharply outlined in the near-surface layers, does not appear at depths of 200—300 m. From this it becomes clear that the subsidence of this area was slow and insignificant after the development of the talus (Plio-Pleistocene).

Similarly, the rest state of the area is delineated on the region of the present depression of the Körös rivers too. From the fact that primarily lacustrine (Levante) fine-grained sediments are to be found in the levels examined in the northern and north-eastern half of South Hungary east of the Tisza, it follows that the subsidence of this area stagnated in the Levante, and the earlier-formed basin part was filled in. It must be noted that the Körös talus system, subsided and demonstrable on the basis of surface and near-surface investigations, is indicative of the renewed subsidence of this area in a relatively young age; moreover, this movement tendency, at the end of the Pleistocene or in the Old Holocene, was of high intensity.

Map 10, depicting the percentage sand contents of the strata of the levels between 300 and 400 m, was constructed in an analogous manner, and by processing of data from the same sources as for the levels between 300 and 200 m. If Maps 9 and 10 are compared, above all the great similarity is apparent: they strongly outline the considerable facies-difference between the south-western + western and the eastern + northern halves of the area. Indeed, in the 300—400 m levels the western, coarser-grained band broadens out and becomes increasingly more sandy in the southern half. At the same time, the sediments in the central area of the Maros talus are even more fine-grained than in the layers above them.

Map 11, showing the bed-relief of the Levante layer complex of South Hungary east of the Tisza, was constructed on the basis of the processing and evaluation of the layer descriptions, electrically-surveyed profiles, etc. of hydrocarbon-prospecting borings made before 1967, and provided to us by the OKGT. Our map differs appreciably from map no. 7 with the same name in the "Hydrogeological atlas of Hungary". We consider the cause of the differences to be the fact that the cartographers who prepared the map for the hydrogeological atlas were compelled to interpolate on the basis of substantially fewer data, since the material from the large number of hydrocarbon-prospecting drillings made recently in the area was naturally not available to them. Even in connection with our map, however, it should be noted that the data network on the basis of which it was prepared is not equally dense in all areas: there are some districts in South Hungary east of the Tisza where even at present we have insufficient data and hence the interpolation is still open to some question. In such districts we were forced to rely on the data of the oil-prospecting drillings that have been made, and in their absence on the more uncertainly assessable data of artesian borings. Such areas are the north-eastern quarter of South Hungary east of the Tisza, and the Hódmezővásárhely—Szentes district.



12.

Fig. 12. Bed-map of the pannonian stratum in South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)
The numbers on the contours denote absolute bed depth in metres

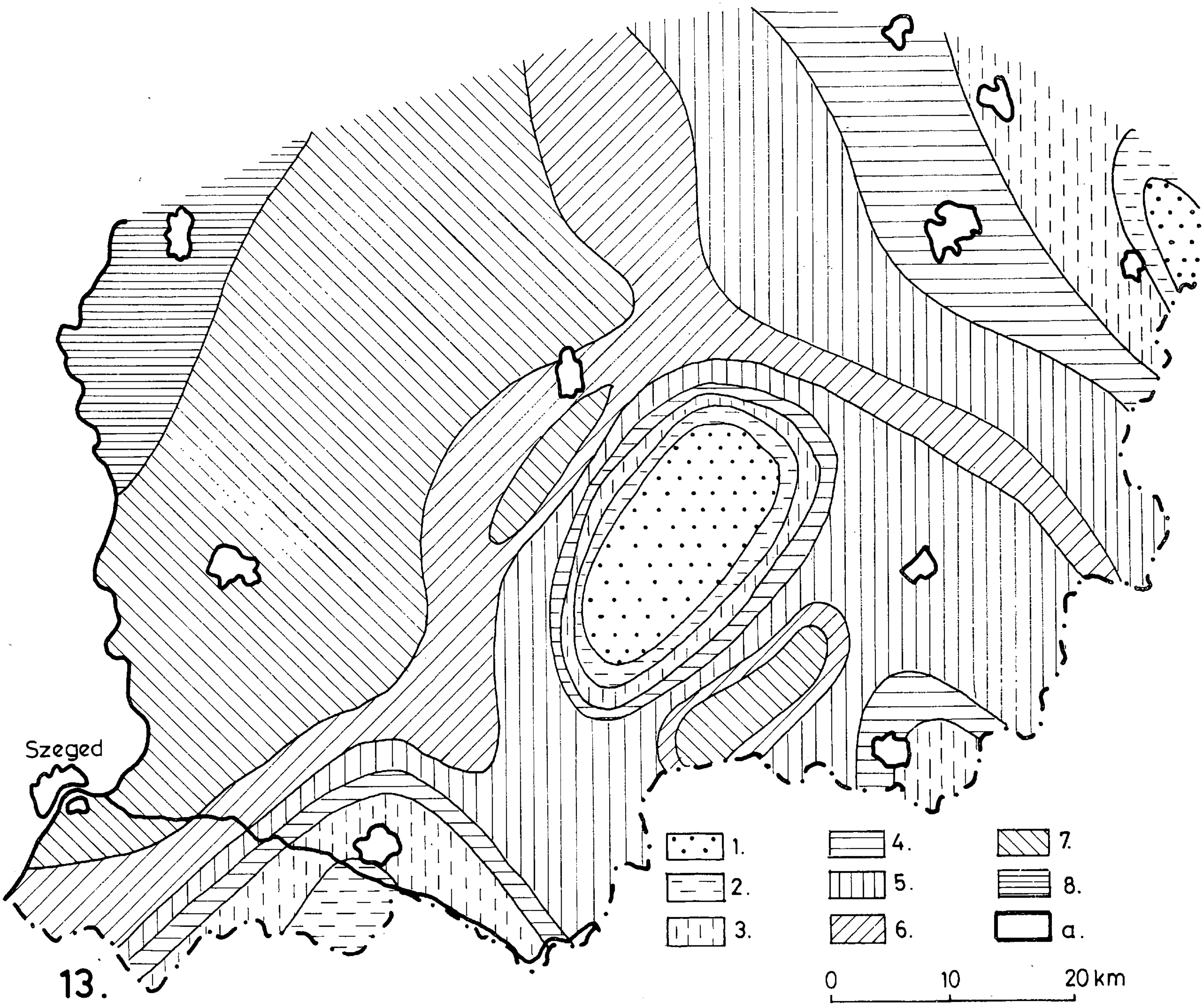


Fig. 13. Map showing thicknesses of pannonian layers with porosities above the limiting value in South Hungary East of the Tisza

(Prepared in the Dept. of Physical Geography, Attila József University, Szeged)

Total thickness of the porous Pannonian layers:

1 = 50 m, 4 = 400— 600 m, 7 = 1000—1200 m,
2 = 50—200 m, 5 = 600— 800 m, 8 = 1200 m
3 = 200—400 m, 6 = 800—1000 m, a = settlement

From a study of the map, it may be stated that the position of the Levante bed reveals two well-distinguishable basins in this area, and one table-land, rising above the general terrain. Of the basins, the western one can be denoted by the Szentes—Hódmezővásárhely axis, and the other, deeper one by the Gyula—Békés-csaba—Mezőberény axis. Besides these depressions, in the south-eastern corner of the area the Levante bed shows up a table-land rising above an absolute height of 400 m; areally this almost coincides with the extent of the later Maros talus.

As regards the relative level-difference of the order of 400—600 m, and the fairly areal and uniform facies conditions characteristic of the initial stages of the Levante, on the basis of these we may explain the differences in bed depth only by the different dynamics of sedimentation of the various parts of the area. Otherwise, in this respect the nature of the movement mechanism displays a striking parallel with the geokinetical tendencies to be observed in Maps 12 and 14.

From a study of Map 12, which shows the bed-relief of the Pannonian layer complex of South Hungary east of the Tisza, it may be established that the Pannonian bed sharply outlines a table-land tapering and becoming lower towards the north-west; the axis of this coincides with the line Battonya—Orosháza. The highest part of the table-land is situated near Battonya.

A second, but much less prominent table-land also appears east of Szeged. The highest and most central part of this lies between Szeged and Maroslele, on the bisector of the straight line joining the two places, and the table-land lies along a longitudinal axis from north-west to south-east, by and large parallel to the previously-mentioned Battonya—Orosháza table-land. Between these two anticlines, the position of the Pannonian bed indicates a trough broadening out in the north-north-west direction, the deepest central part of which lies between Hódmezővásárhely and Szentes, at an absolute depth of more than 4000 m.

The second Pannonian bed depression of South Hungary east of the Tisza is the Sárrét—Békés basin; however, in our research area this does not attain a depth greater than 3500 m, and it appears to be wider and flatter than the Szegvár depression. The deepening of this Békés depression in the Miocene was therefore of lower intensity than that of the Szegvár depression. All these very significant level differences make indisputable the selective subsidence of the area, discussed above.

In the construction of Map 13, depicting the thicknesses of the Pannonian layers with porosities above the limiting value, attention was paid to the positions of the layers of the Pannonian overlay and bed, to their depth relations, to the thermal water reserves stored in the Pannonian stratum, to the electrically-surveyed profiles of prospecting drillings, and to the water yield data of wells producing thermal water.

From this map it may be stated that during the duration of the Pannonian the most intensively subsiding part of the area was the basin of the Tisza valley; abundant thermal water-containing layers from the Pannonian are found there too, primarily in the region of Szentes—Szegvár. Apart from this extensive basin, however, there are further smaller maxima in South Hungary east of the Tisza, e.g. east of Mezőhegyes, between Orosháza and Békéssámson, and also the area between the two Körös rivers. In contrast, in the region of Kaszaper—Tótkomlós the Pannónian layers are thinner, and in addition the porosity index of the rock is lower.

Map 14, illustrating the substratum relief, was prepared by reconstructing and supplementing the map of VIKTOR DANK. It must be noted, however, that the data from some newer drillings suggest that further corrections of the map will be necessary, particularly in the southern and south-western quarter. For example, in the region of Makó the substratum is deeper, while in the region of Algyő—Deszk—Ferencszállás it is higher than indicated on the map. Disregarding these subsequent refinement details, however, the substratum relief even now clearly indicates the tendencies of the ancient geographical development, sharply emphasizing the process of the Erdélyi island hills, outlined along the Battonya—Orobháza axis, with maximum at Battonya. This is surrounded by a broad and deep, semicircular basin-trough, which can be resolved into a wider, but flatter northern part-basin, and a narrower, but deeper western part-basin. The centre of the latter is Hódmezővásárhely, and its meridional axis-line is the preformational factor of the ancient Tisza valley.

In addition to the basin-bottom large forms to be discerned from the map, there are naturally also smaller part-basins, ridges and upthrusts on the surface of the substratum. A sufficient number of data for their detailed construction are not yet available, however. Since these microstructures are scarcely likely to have had any determining significance as regards the later course of development of the ancient geographical picture, we did not make a special effort to depict them.

We shall not deal with a detailed evaluation of Map 15, a gravitational map of South Hungary east of the Tisza. To emphasize its salient features, however, it must nevertheless be pointed out that there are two larger and two smaller gravitational maxima and one more extensive gravitational minimum in the region. The maxima are as follows:

1. The district of Kiszombor—Ferencszállás in the south-western part of the region. This district, with a high positive anomaly, projects towards the north-west beyond the line of the Tisza, while in the south-east it extends to the south of Makó. Areally, it coincides with the deepest trough of the substratum. 2. The second extensive part with a positive anomaly is the regions between the Körös rivers, from Gyulavár, Kétegyháza, Békéscsaba and Doboz up to the border of the country. 3. The third area with a gravitational maximum, smaller than the first two, extends south-east of Battonya across the border of the country.

In contrast with the above three maxima, in the area of the Maros talus there is an extensive region with a negative gravitational anomaly. Within this, a number of smaller, but well-definable gravitational part-basins can be discerned. Examples may be found about 6 km north-east of Békéssámson, about 4 km south of Mezőkovácsháza, and extending from Kevermes to Dombegyháza. The most significant of them is the Békéssámson gravitational depression, centred at Kardoskút.

Because of the higher positive anomaly values, a special position is occupied within the zone with a high negative gravitational anomaly by the nucleus situated 4 km north-west of Dombegyháza; this can not be evaluated surface-morphologically. In the other parts of the region, and primarily in the northern and north-eastern parts, fields of large areality show up, which are fairly monotonous from a gravitational aspect; on the basis of these, conclusions can not be drawn as to the deep-deep-structure and areal movement tendencies there.

Map 16, a geokinetical map of South Hungary east of the Tisza, the regional units with different geokinetical characteristics can be distinguished very well. The most strongly subsiding part is the area between Hódmezővásárhely and Orosháza, from which a narrow trench extends to the south in the direction of Deszk and Új-

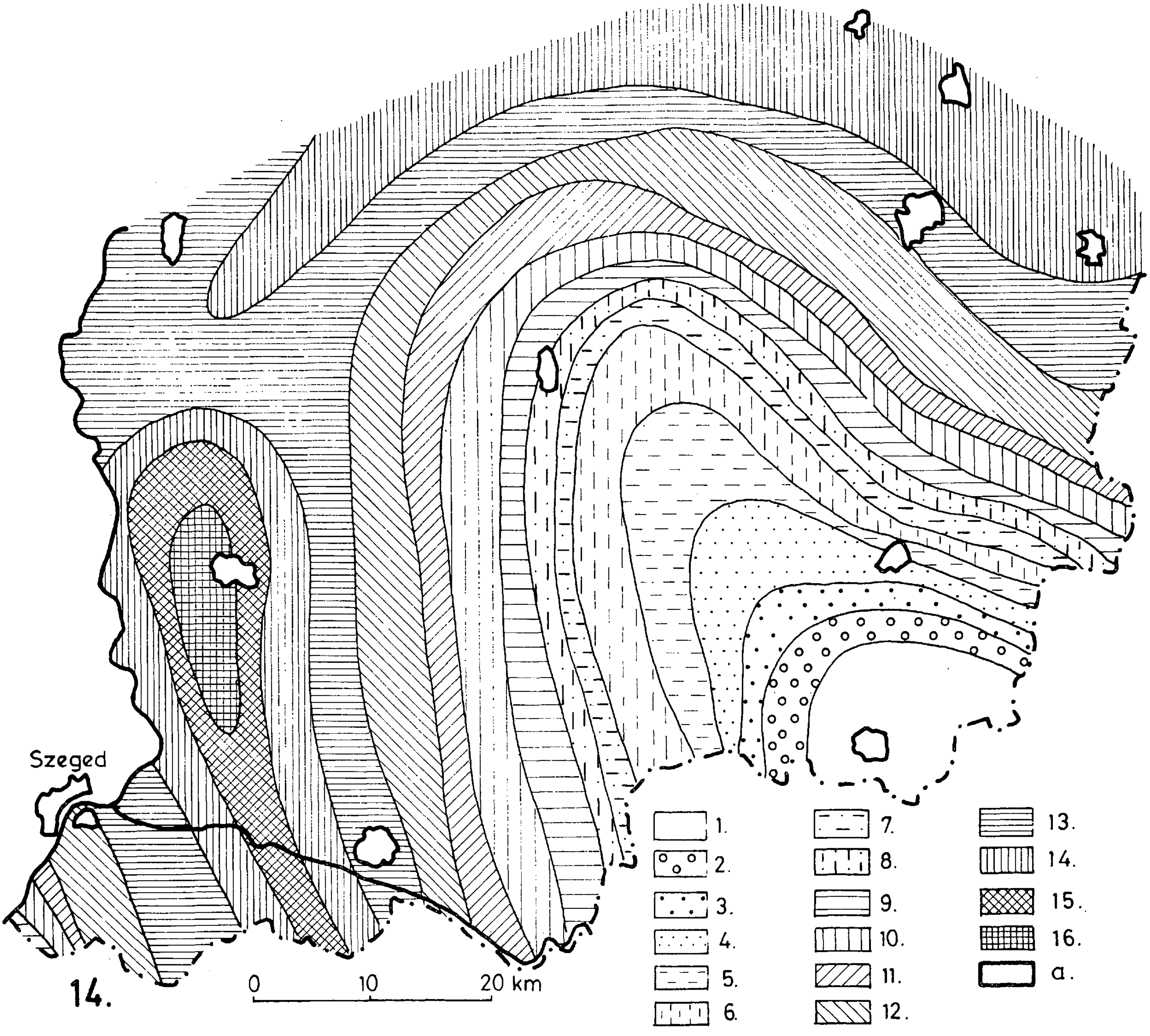


Fig. 14. Relief map of substratum in South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged, on the basis of the data of V. DANK)
Depth of substratum:

1 = 1000 m,
2 = 1000—1200 m,
3 = 1200—1400 m,
4 = 1400—1600 m,
5 = 1600—1800 m,
6 = 1800—2000 m,
7 = 2000—2200 m,
8 = 2200—2400 m,
9 = 2400—2600 m,
10 = 2600—2800 m,
11 = 2800—3000 m,
12 = 3000—3200 m,
13 = 3200—3400 m,
14 = 3400—3600 m,
15 = 3600—3800 m,
16 = 3800
a = settlement

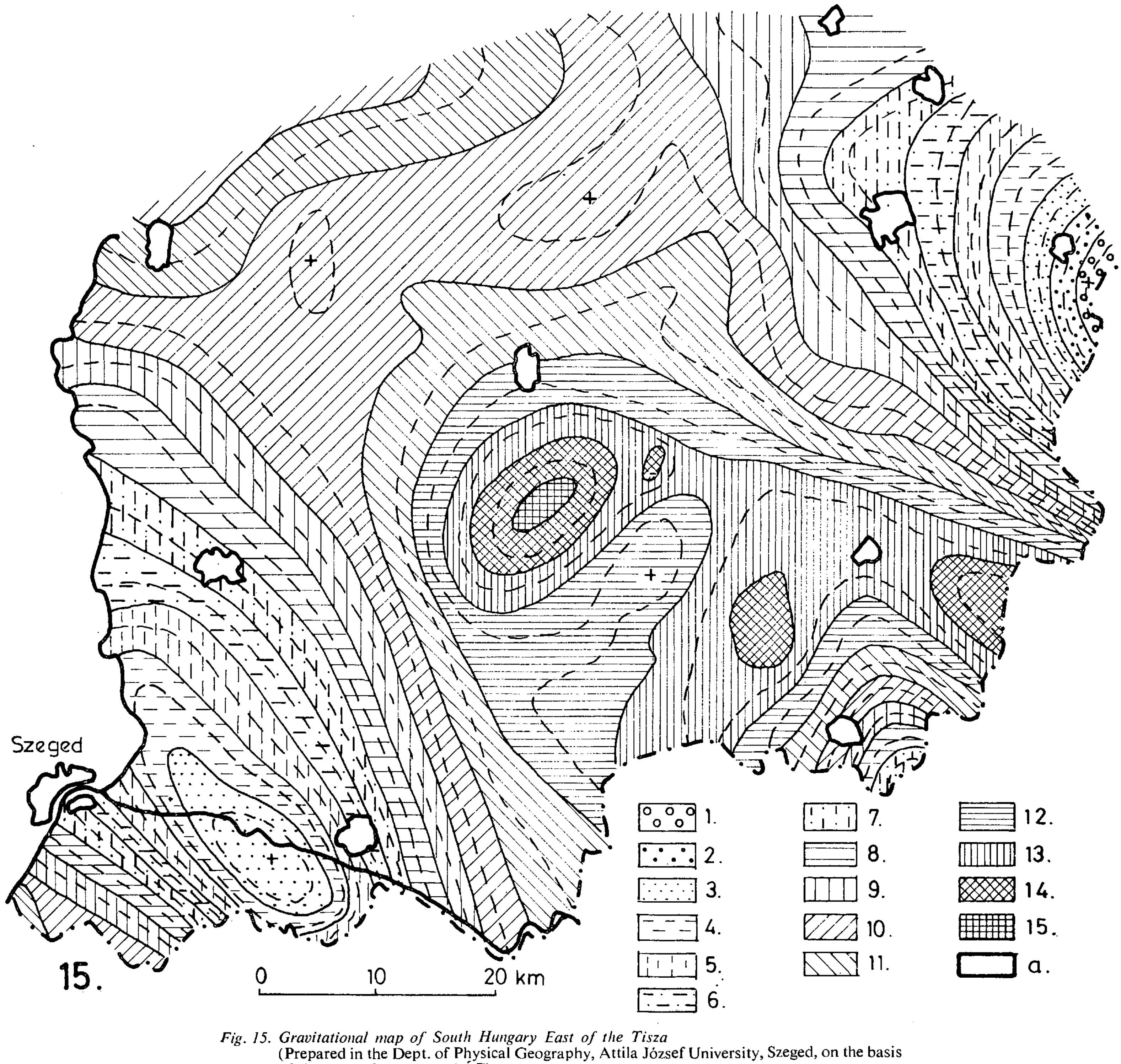


Fig. 15. Gravitational map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged, on the basis of the map of Mrs. I. HAÁZ)
Gravitational anomaly value units:

1 = +25—+23	6 = +15—+13	11 = +7—+5
2 = +23—+21	7 = +13—+11	12 = +3—+1
3 = +21—+19	8 = +11—+ 9	13 = +1—−1
4 = +19—+17	9 = + 9—+ 7	14 = −1—−3
5 = +17—+15	10 = + 7—+ 5	15 =—3

a = settlement

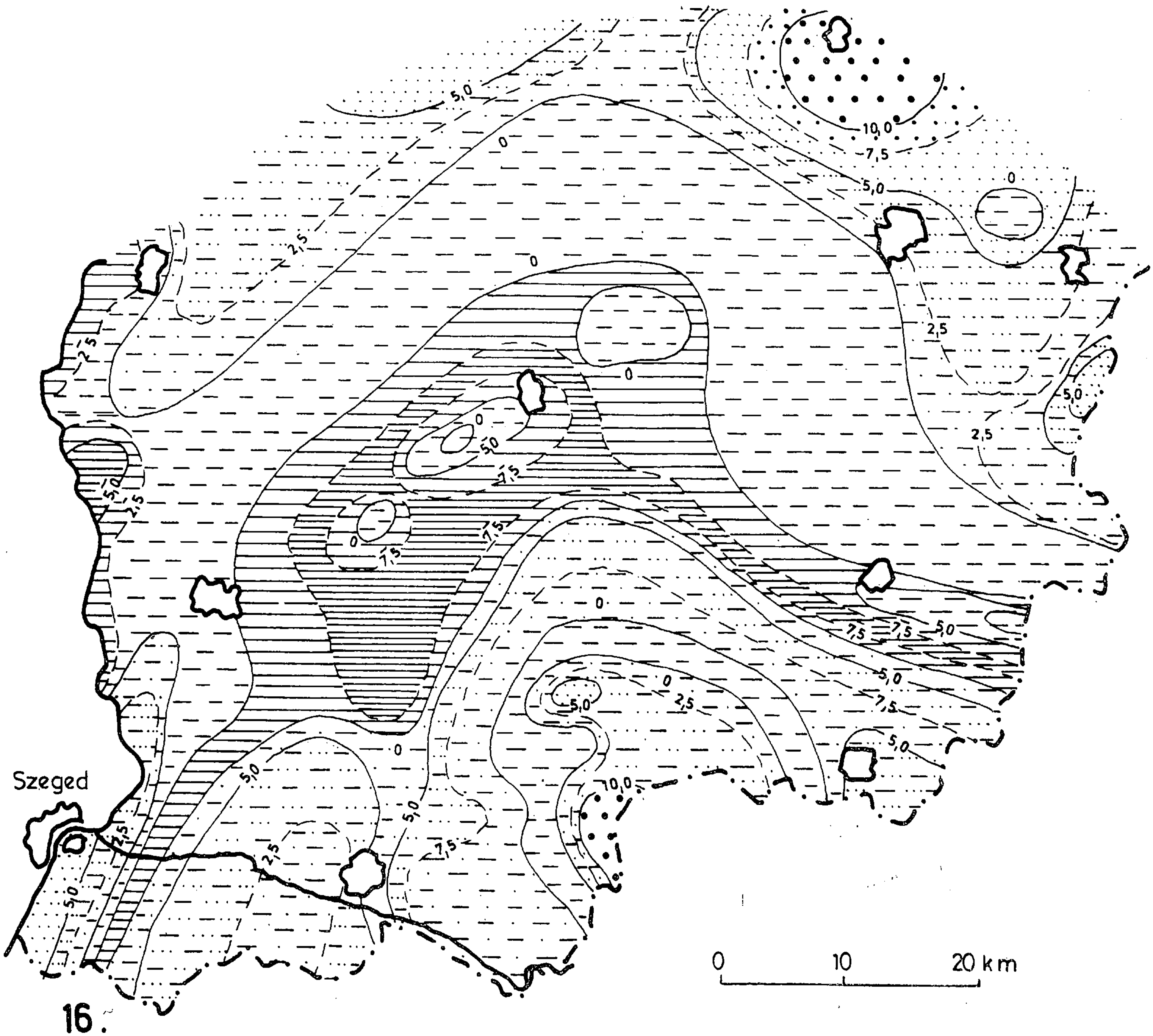


Fig. 16. Geokinetical map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged, on the basis of the map of L. BENDEFY.) The signs and numbers on the isokinetic lines denote the direction and order of magnitude of the movement

szentiván, and another to the east towards Nagybánhegyes and Kunágota. These intensively subsiding bands are probably connected with tectonic lines and trenches. The second relatively strongly subsiding area is the section of the Tisza valley between Szentes and Mártély. At the same time, the region includes rising nuclei: the district of Szeged-Algyő, the district of Kübekháza—Maroslele—Makó, the district of Csanádpalota—Ambrózfalva—Mezőhegyes, the surroundings of Battonya, and the north-eastern maximum between the villages of Békés, Murony and Mezőberény, as well as the maximum observed in the district of Szarvas—Kunszentmárton.

However, since these geokinetical bands and nuclei are in contradiction in a number of places with the clear-cut movement-tendencies revealed by the geological, geophysical and geographical information of a different nature, the question must be raised as to whether significant and misleading sources of error are produced by pseudo-geokinetical movements (e.g. compaction of sediments, swelling of water-permeated soil layers, frost swellings, etc.) in excess of the possibilities of error permitted by the accuracy of the measurement method. The fact that the most rapidly subsiding area is on just that part of the Maros talus where the developmental thickness of the looser sediments covering the substratum too is large, is at any event food for thought.

According to Map 17, depicting the geothermal gradients of South Hungary east of the Tisza, a clear-cut correlation between the gradient value and the thermal water reserve in the layers can not be demonstrated everywhere. For instance, while it is natural, and even of necessity to be expected, that the gradient value is small in those parts where the substratum crossed by the break-lines is close to the surface (Maros talus), and at the same time the value of the gradient is large in the thickly-filled up geosynclines (the district of Szentes—Szegvár, the basin of the region between the Körös rivers, the area of Kondoros, this logical tendency is completely contradicted by the area with a low geothermal gradient index adjacent to Szeged (between Maroslele, Szőreg and Kübekháza), since in this part the thickness of the loose-structured strata is very high (cf. the substratum and Pannonian bed maps). Because of this, it is probable that it is necessary to reckon in the latter area with intensive and quite young break-systems (between Maroslele and Ószentiván) permitting the flow of the thermal water of the deeper layers to the upper layers. It may occur that these same lines may also play a role in this area in the upward migration of the hydrocarbons.

Map 18, showing the geothermal isoanomalies, was prepared on the basis of the map with the same title of L. BENDEFY. However, in addition to simple reconstruction, certain modification too was employed, for we used as reference not the national average level at a depth of 374 m, but the national zero point. Thus, with the aid of our isoanomaly lines we can read off the areal position of the 30 °C geoisotherm level directly in metres.

Evaluation shows that there are certain contradictions between the geothermal gradient map, Map 17, and Map 18 insofar as the isothermal relief units of the geothermal gradient map rea not outlined on the geothermal isoanomaly map. However, the anomaly maximum and minimum areas of the geothermal isoanomaly map do not coincide with the geological and deep-structural main kinetical areal units either. Hence, this map raises further open questions, elucidation of which would demand further detailed data collection and assessment work.

While this paper has so far involved an analysis of South Hungary east of the Tisza from some special aspect, and with the aid of objective-maps corresponding to this aspect, we must now carry out the complex evaluation of the region; that is, a study must be made of those natural geographical surface development tendencies which strengthen one another in the information of the maps prepared in accordance with the various aspects, and also those which weaken one another in their complex comparison. At the same time, the results of the comparative dynamic regional analysis must also be evaluated with regard to the aspects of hydrocarbon prospecting. Only this can describe the society-centred conception of the entire research work and also the balance of its possible economic usefulness.

In the course of the comparative evaluation of the eighteen maps, the most important and most prominent ancient geographical developmental tendency emerging is the permanent geokinetical character of certain parts of the region, lasting since the end of the Tertiary. We must see that the present tendency of the neotectonism is even today expressing the old regional charateristics of the geokinetical dynamism. In this respect me must set out from the substratum map (Map 14), which clearly outlines the thundamental regional surfac relief differences of the alaeozoic-Mesozoic and crystalline substratum.

As we pointed in the description of Map 14, it is characteristic of this region today that there is a table-land rising high in comparison to its environment and sloping from south-east to north-west (the Battonya—Pusztaföldvár block trend), and this is surrounded in a semicircle from the west and the north by a deep fairly wide depression region, the deepest parts of which are to be found deeper even than 4000 m.

Although the substratum map does not show it, because the available deep boring data were still deficient at the time of its constuction (1967), it is now known that in the south-west corner of the region, in the district of Algyő—Klárafalva, there is a second substratum uparching (block trend?), lower than the previous one, with an axis roughly parallel to the line Battonya—Pusztaföldvár. The position of this is outlined on both our Pannonian bed map and also the gravitational map (Map 15). It is to be noted in connection with this that along the axis of this substratum table-land from Algyő to Klárafalva the Pannonian lies directly on the substratum, while a few km from it to the west and (perhaps) the east there is present the deeper-levelled Miocene too, from which it follows that the table-land in question was produced by pre-Pannonian tectonics. In addition, however, it is necessary to reckon with the post-Pannonian and even the present elevation of this table-land; apart from the very high value of the positive gravitational anomaly, this is indicated by the geothermal gradient values, which here are in contradiction with the general geothermal gradient tendency in the region (see eveluation of Map 17), and by the "kinetical trench" of the geokinetical map at Deszk (see evaluation of Map 16).

Another question awaiting decision was the clarification of the tectonic nature of the movement mechanism, including now the problem of whether the movement of the substratum is that of a fracture-structured block mountain, or whether it is developing with a tendency of geosyncline and anticline formation of a flexural nature.

In this respect our view is that, although smaller parts of the larger units may have moved block-like along the fracture planes, and local trench depressions or upthrusts too may have been formed in this way, nevertheless the fundamental

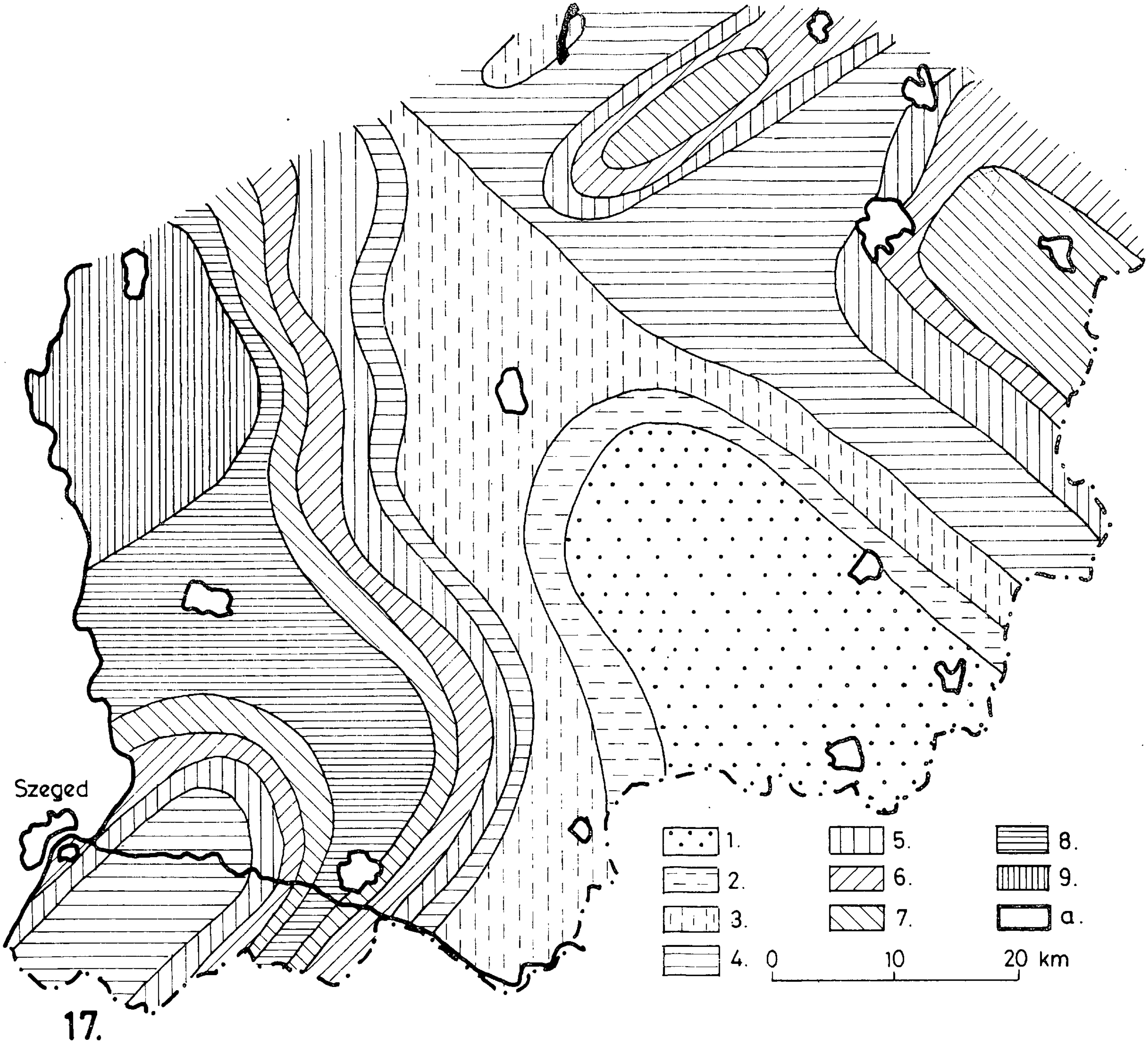
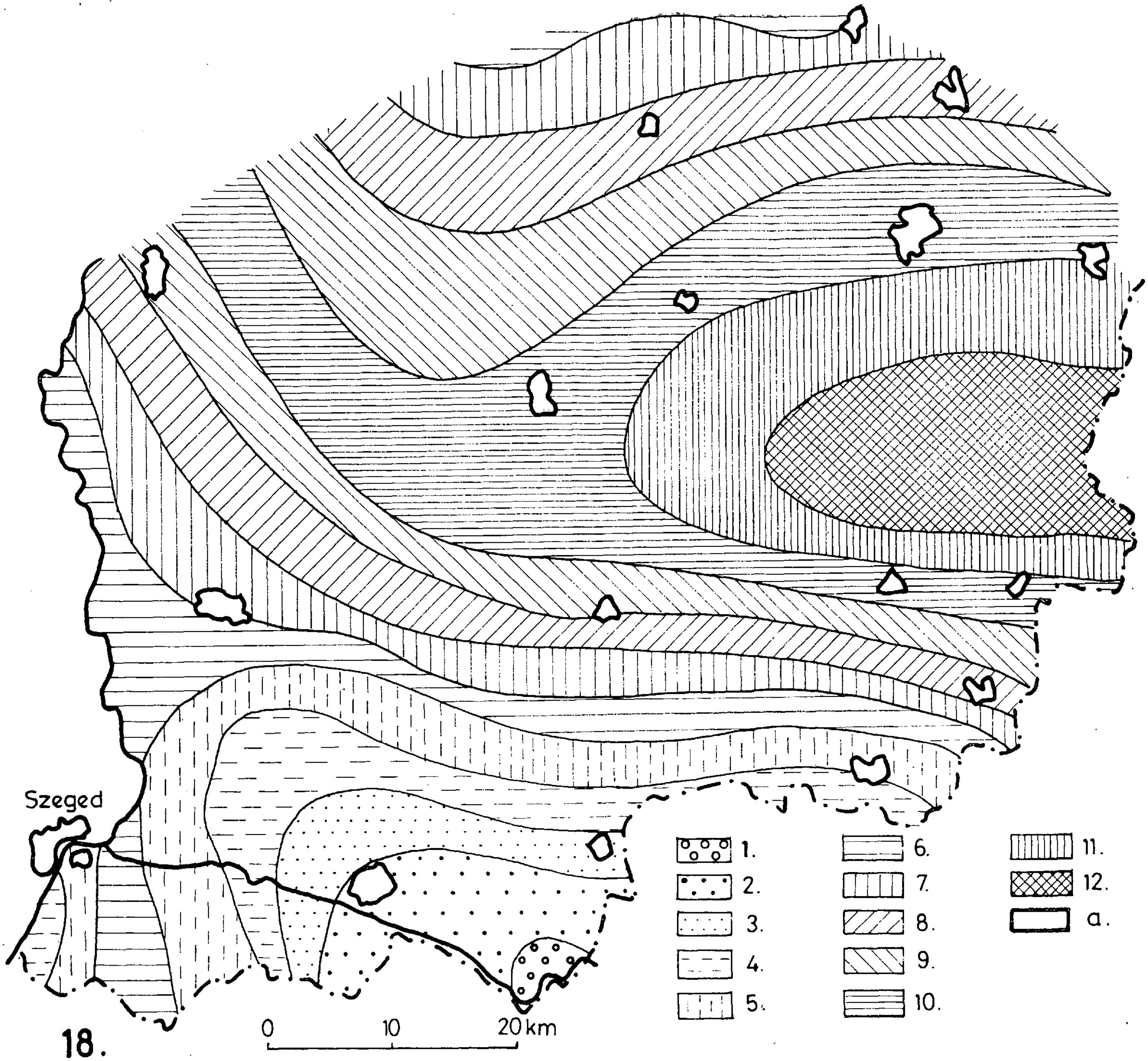


Fig. 17. Geothermal gradient map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged, on the basis of the data of. J. URBANCSEK.)
Value of geothermal gradient (m/°C):

1 = 15,	6 = 20,
2 = 16,	7 = 21,
3 = 17,	8 = 22,
4 = 18,	9 = 23,
5 = 19,	a = settlement



18.

Fig. 18. Geothermal isoanomaly map of South Hungary East of the Tisza
(Prepared in the Dept. of Physical Geography, Attila József University, Szeged, on the basis of the map of L. BENDEFY)

Depth of 30 °C geothermal isoanomaly surface:

1 = 414 m,	7 = 364—369 m,
2 = 404—414 m,	8 = 354—364 m,
3 = 394—404 m,	9 = 344—354 m,
4 = 384—394 m,	10 = 334—344 m,
5 = 374—384 m,	11 = 324—334 m,
6 = 369—374 m,	12 = 324
a = settlement	

movement tendency of the region is characterized by the long-lasting subsidence of the geosynclines, and by the slower, but similarly long-lasting subsidence of the demonstrable substratum table-lands compared to these; that is, a geosyncline-like subsidence with intensities differing from place to place is characteristic a permanent manner of the entire region, so that within the whole the individual parts display increasing level differences with a folded-mountain aspect.

Comparison of the Pannonian and Levante bed maps (Maps 12 and 11) with the Pannonian porosity map (Map 13) and the sand-content maps of the upper layers (Maps 10 and 9) provides convincing evidence that the tendency of the movement has essentially not undergone any change anywhere since the end of the Tertiary; that is, nowadays too the same regional parts are the most subsiding sediment catchments, in which both the Pannonian and the Levante lacustrian layers show the thickest accumulations. (Here it must be pointed out that there is no longer such a clear-cut correlation in the Pleistocene strata; however, this does not appear as a contradiction, since the Pleistocene strata are predominantly fluvial deposits, the accumulational areal distribution of which is more strongly affected by the regularities of the running-water sediment formation of a different nature.) Otherwise, the remarks in the explanatory text to Maps 1, 3, 4 and 5, the contour map, the connate water map, the recent slope-tendency map and the surface geology map, respectively, prove the areal distribution and characteristics of these same movement feature referred to the present.

From the result of the ancient geographical investigations reported here, therefore, it follows that there are two large sediment-catchment geosynclines in South Hungary east of the Tisza:

1. One of these can be denoted by the axis line Makó—Hódmezővásárhely—Szentes. The deepest part (centre) of this is situated between Hódmezővásárhely and Szentes (see Map 12). The sediments deposited into the geosyncline become finer on proceeding from its central part in the direction of the edges, and even peter out while the layers are the coarsest-grained in the central parts of the geosyncline (see Maps 13 and 10). The more porous layers petering out towards the rim parts (particularly in the direction of the wings of the Algyő—Deszk and Battonya—Pusztaföldvár anticlines) fold up on the petering-out lens ends.

This structure ensures the possibilities of hydrocarbon accumulation and storage in the folding-up and here petering-out rim-positioned, more porous Pannonian layers of the geosyncline, assuming that the strata to be regarded as mother rock are in the central and deepest-situated part of the geosyncline.

According to our geosynclinal dynamic natural geographical conception described, the possibility of hydrocarbon occurrence may therefore be reckoned with in the south-west syncline wing (Algyő—Klárafalva—Maroslele—Ferencszállás), and also in the traps formed in the eastern syncline wing (in the vicinity of the Nagylak—Csanádpalota—Pitvaros—Tótkomlós—Kardoskút axis). If the north-east to south-west lens in the Fehértó district of Kardoskút in Map 13 is taken into consideration, which denotes a more favourable position compared to the other points of the trend from the aspect of possible storage conditions, we might perhaps think that the most favourable ancient geographical conditions of hydrocarbon occurrence within the eastern syncline wing are most probably given in the district of Békéssámson—Kardoskúti Fehértó—Kardoskút.

2. The other large sediment-catchment geosyncline of South Hungary east of the Tisza is the Körös geosyncline with Gyula—Békés axis, the central and deepest part of which is in the district of Gyula and, proceeding south-eastwards across the border from there, under Roumanian territory (see the concordant evidence of Maps 11, 12, 13, 15 and 17, and Maps 3, 5, 9 and 10). Insofar as the conditions of hydrocarbon formation were given in the Pannonian in this geosyncline, by analogy hydrocarbon occurrence is similarly to be expected in the petering-out and folding-up sediment lenses of its wings, that is in the district of Nagykamarás—Kunágota—Medgyesegyháza—Magyarbánhegyes—Csanádapáca—Pusztaföldvár).

Insofar as the north-east to south-west post-Pannonian fracture-lines structured the table-land with the Battonya—Pusztaföldvár axis (such post-Pannonian the
the table-land with the Battonya—Pusztaföldvár axis (such post-Pannonian movements may be considered as possible on the basis of the gravitational map), the vicinity of the anticline axis; this means that hydrocarbons may also be hoped for along the line Battonya—Pusztaföldvár. In connection with this, however, it is our view that, although this line is undoubtedly in an arched situation, nevertheless (because of the more compact sediment structure of the layers) the storage possibilities are more unfavourable (particularly for liquid hydrocarbons) than in the north-eastern anticlinal wing, where the more porous layers of the Gyula geosyncline peter out in an upwards direction.

3. Although in the bulk of its extent it does not lie in the region of South Hungary east of the Tisza, we nevertheless consider it reasonable to mention that our investigations suggest that a third large sediment-catchment basin too may play a role in the possible hydrocarbon production of South Hungary east of the Tisza. This is the geosyncline to the south-west of Szeged, the bulk of which lies in the area between the Danube and the Tisza and is in Yugoslav territory; within the north-east petering out wing of this, in our region we may consider favourable storage possibilities perhaps along the direction-line Kübekháza—Újszentiván—Dél Szeged (see the corresponding areas of Maps 12, 15, 16 and 17). (It should be noted that since the drafting of this paper (1967), of these places Szeged—DÉL has already proved fruitful.)

On the basis of the dynamic natural geographical regional evaluation, apart from those already mentioned, other geosynclines and rim-positioned storage possibilities connected with these can not be detected in this region. Thus, the existence of the "large Békés depression between Békéscsaba and Nagyszénás", assumed by the OKGT, was not confirmed on the basis of the results of our investigations. According to our research, special arguments justifying hydrocarbon prospecting are not found for the distrinct of Szentes—Nagymágocs. (The few gas-containing artesian wells of lower depths in this part of the region can be brought into genetical correlation with the methane production of the peaty layers of the Levante lacustrian sediments here.) In contrast with this, the arguments of the dynamic natural geographical regional evaluation suggest that the areas denoted in detail above, among them the area to the east of the Battonya—Pustaföldvár block trend, can be recommended for prospecting.

As regards the large Hódmezővásárhely—Makó depression to the east of Algyő, our investigations strongly suggest that this is only a process of a larger geosyncline, the central trough of which is probably between Hódmezővásárhely and Szentes; we are of the opinion that the more favourable hydrocarbon-occurrence sites must be sought primarily not along the syncline axis between Makó and Hódmezővásárhely, but in the wings lying to the west and east of this, in the areas of the bands already named in detail above.

To close, it should again be emphasized that the task we have attempted to carry out to the best of our ability was a new one; such an evaluation of the natural geographical regional development (directed to the aspects of hydrocarbon prospecting) can in many respects be regarded as an untrodden path, not only on a Hungarian scale, but also internationally. It stands to reason, therefore, that for this reason too our overall conclusions, which are also projected to the indication of the possibilities of each hydrocarbon-storage area, can convincingly confirm the correctness of the scientific research method (and even principle) we have followed, if our conclusions (which on occasions are still of a hypothesis nature) are proved by the concrete results of later exploratory and prospecting drillings.

We very much hope that this will be the case, for in this case the economic successes may also mean the broadening of the possibilities of utilizing science. However, even now it may be considered in all probability that we are concerned with a new conception of natural geographical research and regional evaluation, presented here on a regional example, which involves many progressive criteria and up-to-date features of the further development of science.