NEW RESULTS ON LANDSCAPE BOUNDARIES

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Abstract
The correct delineation of geographical and landscape ecological units, being the fundamental territorial domains of both physical and human geography, is very important from the aspect of several other related disciplines as well. It is hard to tell how distinct landscape units, or landscape ecological units can be, from a statistical point of view. The present study investigates how well-defined (definable) geographical units (landscapes, landscape types) are in a statistical and mathematical sense. Since landscape forming factors do not exhibit distinct boundaries either, during the analysis it is better to consider them as ecotones. Integration of factors, and the unclear interpretation of present landscape boundaries do further complicate the sound mathematical evaluation of the studied geographical units. In order to resolve these problem GIS techniques were applied.

Keywords: landscape types, scale, homogeneity, GIS analysis

1. Introduction

The correct delineation of geographical and landscape ecological units, being the fundamental territorial domains of both physical and human geography, is very important from the aspect of several other related disciplines as well (e.g. regional planning, landscape planning, vegetation mapping). In geographical terms these units are integrated from definite natural and social factors, however the system built up this way represents a “grey box”, as the way of integration is not exactly known. This is one reason why it is hard to tell how distinct landscape units, or landscape ecological units can be, from a statistical point of view. The problem gets even more complicated if we consider that the traditional delineation of landscape units is not understood clearly either.

The problem gets simpler if more homogeneous factors are involved to the system (e.g. only physical and natural), however in this case there can be a serious reduction in content unless pure landscape ecological analysis is aimed at. In mathematics and physical geography territorial units are coined as area, as opposed to different sub-disciplines of human geography, using rather the terms of region, district or territory. From these the more general idea of region fits best to the integrated approach outlined above. The present study investigates how well-defined (definable) geographical units (landscapes, landscape types) are in a statistical and mathematical sense. Since landscape forming factors do not exhibit distinct boundaries either, during the analysis it is better to consider them as ecotones. Integration of factors, and the unclear interpretation of present landscape boundaries do further complicate the sound mathematical evaluation of the studied geographical units. In order to resolve these problem GIS techniques were applied.

2. Preliminaries

Landscape is interpreted in many ways. Traditionally it is considered as a unit emerging from the interaction of landscape forming factors, though recently by the spreading of a metric approaches, it is rather understood as a heterogeneous combination of patchy landscape elements, which recur as a whole in a very similar form (Forman, 1995; McGarigal, 1996). The anthropocentric definition of landscapes will eventually result in a geographical interpretation. This approach will be followed in the forthcoming analysis. Several regularities known from landscape ecology can be adapted here, but new problems will also come to the forefront, such as the integration of landscape elements, which is definitely not a challenge during a landscape ecological analysis, investigating objects as an already integrated entity.

The precise definition of geographical units can be addressed in terms of position and content. The accuracy of position was investigated using remotely sensed data by e.g. Richards – Jia (2006), or Foody (2002) in detail. These analyses require a well defined content. The investigation of content accuracy starts with the realization of the inherent structure of the system, however the very first serious problem in this respect is the question of scale. Several earlier researches have reinforced that patterns appearing in the landscape (including that of controlling processes) are scale dependent (Gustafson, 1998; Wu, 2004; Mezősi – Fejes, 2004; Szalai, 2006; Túri – Szabó 2008), in other words each studied organism scales its environment. Every geographical landscape, landscape type and landscape character has got a boundary, in our case the analysis of accuracy is related to this idea.

Scale is a key concept in geography. Whether the object of the research is approached by a physical or human geographical interest the question of scale will definitely be come across. For example it is not difficult to find that at a scale of 1 : 1 000 the degree of soil erosion is very strongly related to the angle of slope, however, if scale is changed to 1 : 1 000 000 then erosive precipitation becomes a similarly important controlling parameter. On Fig. 1. slope exposure data of a Hungarian hilly region can be seen, derived from digital terrain models with different resolution (2.5; 5; 25; 125; 312.5; 625 m). It is obvious that the results are highly dependent on the applied pixel size. As a matter of fact, geographical processes and their results appear very differently if scale is changed. In the case above for example by decreasing resolution patches representing different exposure categories will have a more and more regular shape, and their number will logarithmically decrease.

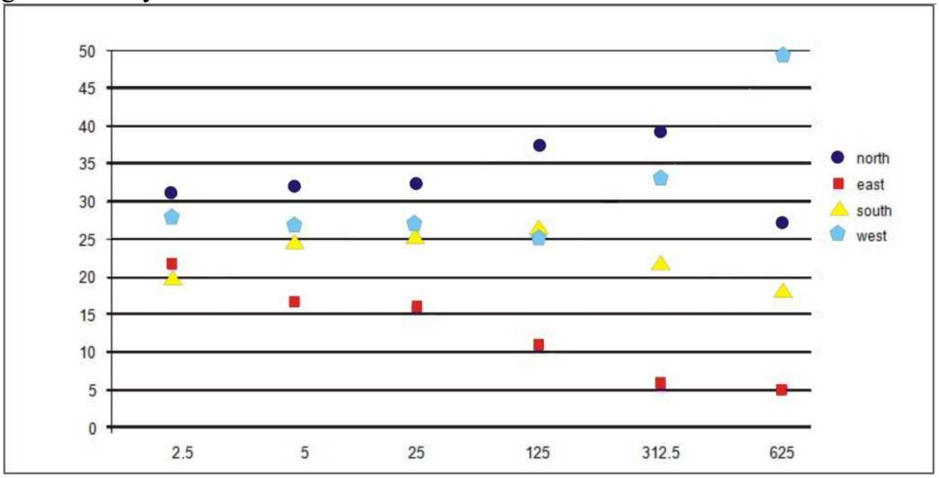

Fig. 1. Percentage distribution of different slope exposure categories in the meso-region of the Mátra Hills.

It is a well known rule that geographical processes acting in a wide range of scales will have a dominant scale of action, and thus, as a system these processes react sensitively to any changes in scale. This problem in itself will generate several further questions: e.g. to what degree the regularities of a given phenomenon will prevail at different scales. Several researchers argue (e.g. Philips, 1995) that (micro) phenomena and processes appearing at large scales provide the "fundamental conditions" for phenomena related to small scales. All this highlights that boundaries (in our case accuracy of content) are only worth to analyse if the scale of investigation and the applied method are well-defined. Since there are several scale dependant features the identification of the optimal scale and resolution is of great importance. For example O'Neill et al. (1996) found that the optimal scale of investigation is 2-5 times the size of the smallest patch (Fig. 2).

There are disciplines where scale is not of key importance (e.g. mathematics), but geography is typically featured by a scale dependant approach: physical geography considers for instance the hierarchy of catchments as a measure of scale, while human geography applies the fairly diverse system of individual, household, settlement, agglomeration etc. Obviously scales can be approached either from a theoretical or a practical direction, but it is true that bearing in mind their importance very useful conclusions can be drawn.

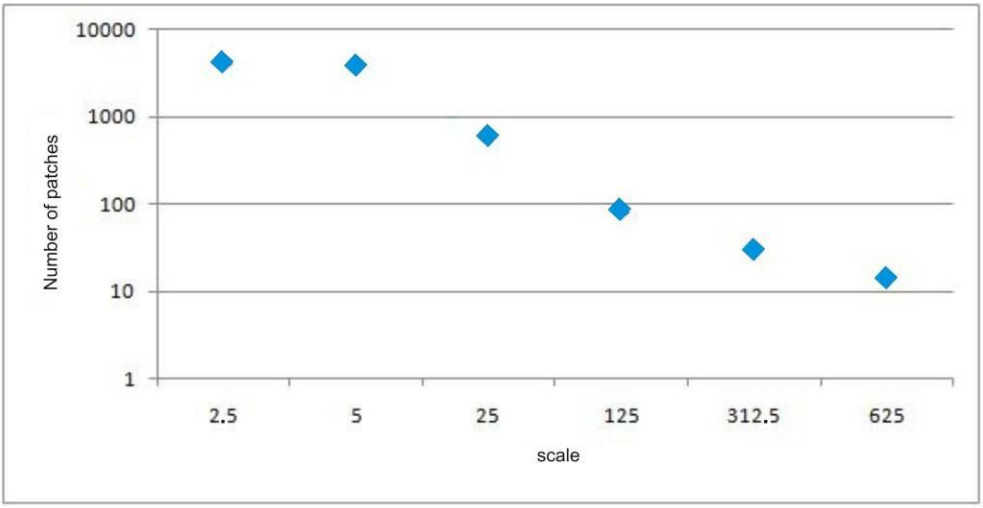

Fig. 2. Relationship of scale and the number of patches in the meso-region of the Mátra Hills.

In some cases landscape units used in landscape ecology are well-defined neither mathematically nor statistically (Mezősi – Bódis, 2001). Consequently, in a previous study we aimed at the precise definition of landscape units in statistical terms. The following method was applied: first different types of variables (ratio, interval, ordinal, nominal) were subjected to cluster analysis, then results were converted to nominal values. Based on the received parameters a map was created which was then compared to a landscape ecological map made by traditional survey methods. By cross-tabulating the two maps we analysed how well-defined the units are in statistical terms.

The present research addresses statistical evaluation not from the aspect of parameters but it rather offers a solution by analysing the boundaries of landscape forming factors.

3. Methods

The degree of definition can also be interpreted as the degree at which landscape units, being integrated from the complex of landscape forming factors, transfer original information. It is however another question how different landscape forming factors can be integrated (in case originally non-integrated factors are applied), and their boundaries defined. Consequently, those landscape units were considered more well-defined from a geographical aspect, which were homogeneous in terms of the investigated controlling variables. For the analysis lithological, soil type and vegetation data were applied, bearing in mind that the parameter set can be enlarged by several further, even human geographical factors.

Parameters were available in a digital format at a scale of 1: 100 000 and 1: 200 000, enabling a micro-region scale, but disabling an ecotope scale analysis. Calculation of homogeneity did not conflict the fundamental assumption of landscape ecology that landscapes and landscape types are characterised by heterogeneity. Here homogeneity stands for the recurrence frequency of the analysed landscape forming factor categories, and as such it is independent from the content of the factors, and seems to provide comparable and neural values for the joint analysis of parameters. The homogeneity estimation applied in the study has of course some weak points which were attempted to overcome. This way those factors were involved in the analysis which were statistically independent (elevation and slope angle are not independent for example) and could be divided into a similar number of categories (Table 1).

Table 1. Important parameters of patches

km^2	*lithology*	*soil type*	*vegetation*	*micro region*
Number of categories	9	9	10	
Number of patches/ landscape units	659	1701	109	230
Mean area of patches/ landscape units	141.2	54.7	853.3	404.5
Area of the largest patch/landscape unit	14467.6	13298.2	4861.4	1829.1
Area of the smallest patch/landscape unit	0.02	0.02	3.2	11.5

During the analysis first the areal proportion of different landscape forming factors was determined within each micro-region. As an example the spatial distribution of lithological categories are shown in terms of the Hanság region (Fig. 3).

The identified 9 categories (1. glacial and alluvial sediments; 2. loessy sediments; 3. Tertiary and older sediments; 4. erubase; 5. limestone and dolomite; 6. sandstone; 7. clay shale and phyllite; 8. granite and porphyrite; 9. andesite, basalt and rhyolite) enabled only a schematic evaluation, nevertheless when all landscape units were taken into account the result was still very mosaic. Lithological border lines evaluated in this way coincide only partially with micro-region boundaries. With the exception of the Great Hungarian Plain the picture is very mosaic, although lithological categories are not very strictly defined. In all only one tenth of micro-regions received a homogeneity value above 90 %, and this clearly underlines what we meant by spatial inaccuracy (Fig. 4).

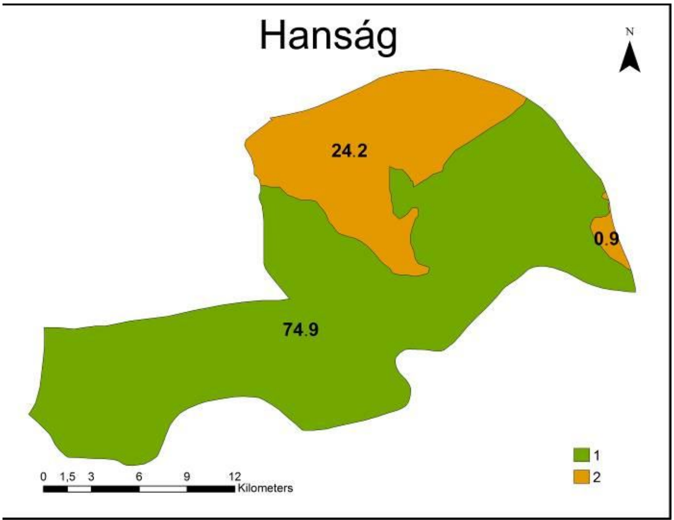

Fig. 3. Lithological homogeneity in the Hanság micro-region (source: AGROTOPO map) 1 – alluvial sediments, 2 – loessy sediments.

Soil type and vegetation homogeneity maps, both factors having 9 categories, were prepared following the same method. The pattern of soil type homogeneity was much more fragmented than that of lithology. The database (MÉTA; Molnár et al. 2010) used for vegetation analysis had an approximately 1: 200 000 scale. Although the authors claim that they determined vegetation based landscape units, the database displays vegetation zone borders rather than true (geographical) landscape boundaries, as these should be the result of an integrated analysis of landscape forming factors. However, during the compilation of the MÉTA map the authors applied some further resources as well (e.g. topographical maps, soil type maps, historical maps, climatic and habitat data). As a consequence the MÉTA based vegetation boundaries overlapped the best landscape unit boundaries, and almost third of the micro-regions turned to be homogeneous in this respect.

4. Results

The more accurately a homogeneity patch of a selected landscape forming factor overlapped the traditional landscape unit, it was considered the more well-defined in a statistical sense. It must be borne in mind however that even for a simple analysis factors have to be carefully selected in terms of scale and independence. A series of t-tests have shown that group difference increases significantly above a 70 % homogeneity value. Therefore those micro-regions were selected, where each investigated landscape forming factor exhibited at least a 70 % homogeneity.

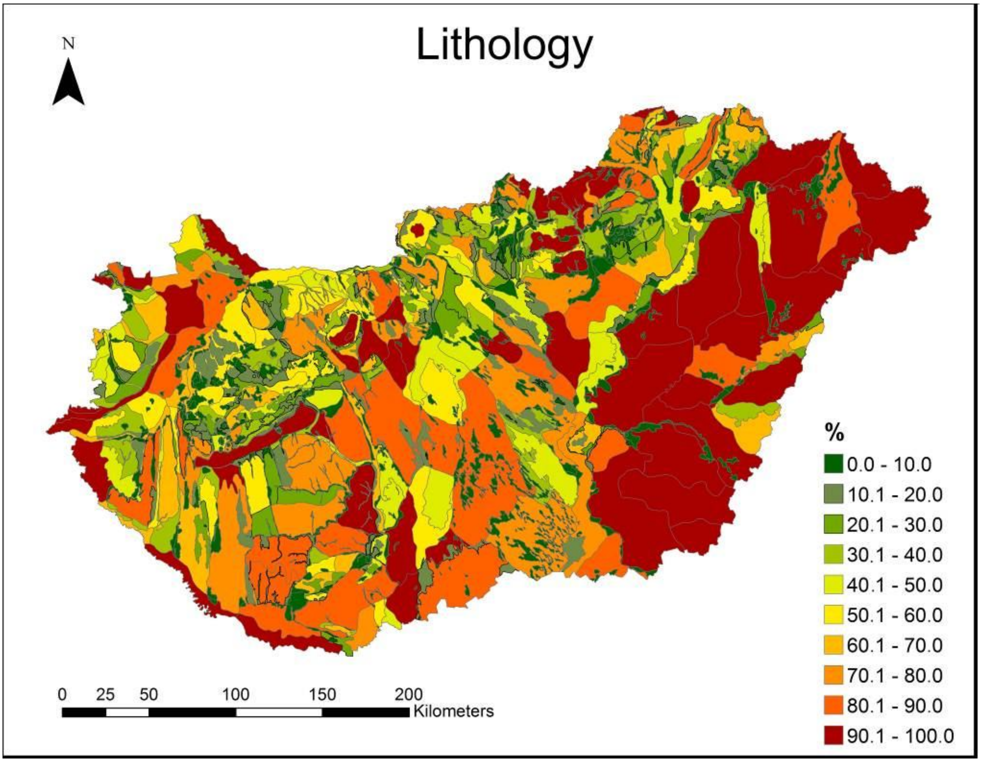

Fig. 4. Homogeneity values derived from the lithological map of Hungary.

Based on the results, 3 % of the country's total area proved to be very well-defined. Landscape units forming this group are the following: Sopron Mountains, Gánt Basin, Parád-Recsk Basin, Alsó Mountain, Torna Hills, Illancs, Békés Ridge, Csanád Ridge. Well-defined units, such as the Bugac Sand Ridge, Aggtelek Mountains, Bükk Mountains occupy a further 21 % of the total area. Thus regarding the three investigated landscape forming factors in all 24 % of Hungary's territory can be considered to have well-defined landscape boundaries from a statistical perspective (Fig. 5). Even if landscape unit boundaries are understood as ecotones and substituted by a wide buffer zone, as it is usual in landscape ecology, the value calculated above will not increase significantly. In this type of analysis the size of the geographical unit is not a measure of importance, and the different weight of elements in defining a variety of plain and mountain type landscapes cannot be determined either. Although different landscape forming factors are handled together, the method cannot integrate them, and will not inform us on the quality of their relationship. However, it provides us the means to determine and compare the degree of definition in a quantitative manner.

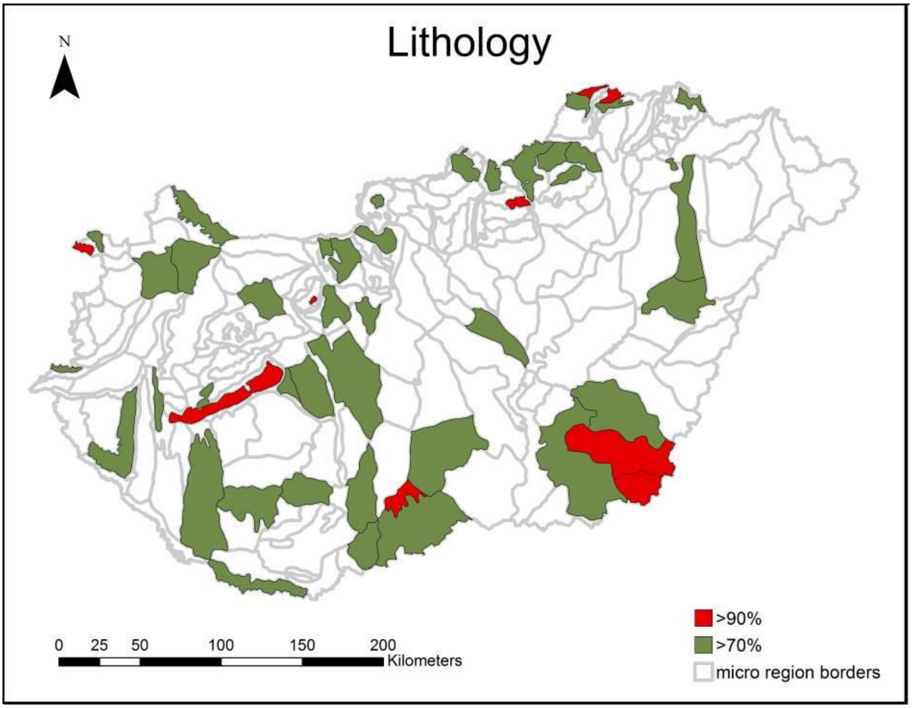

Fig. 5. Statistically well-defined landscape units based on three landscape forming elements. 1 – homogeneity of each element exceeds 90 %, 2 – homogeneity of each element is between 70 and 90 %.

5. Conclusions

In the present research three landscape forming elements were selected (lithology, soil, vegetation) and evaluated jointly by overlaying their boundaries. As a result, 24 % of Hungary's territory proved to be well defined in terms of the landscape. These high homogeneity patches can be considered as statistically uniform core areas of landscape units.

Several methods can be suggested for the verification of our results. One of these is also neutral from the aspect of landscape forming factors, and looks for similarities by intersecting the polygons formed by the different variables. This approach was applied during the compilation of the European Landscape Map, made by the intersection of 1 km resolution polygons of climatic, relief, soil and land cover (CORINE) data, using software eCognition (Wascher, 2005).

Our verification process was similar in terms of neutrality, however it was more straightforward and simple. Landuse was disregarded as a reference as it would have significantly rearrange homogeneity values. In order to ensure the independence of the investigated landscape forming factors in statistical terms a square grid with 1x1 km pixel size was taken, and the homogeneity of each factor was calculated for each pixel on the entire territory of Hungary. Factors were weighted uniformly. Subsequently, the homogeneity layers of different landscape forming factors were intersected by the Intersect tool of ArcGIS. As a result, each grid cell received three homogeneity values representing each landscape forming factors.

Finally, a query was build to select those grid cells where lithological homogeneity was ≤30 % AND soil homogeneity was ≤30 % AND vegetation homogeneity was ≤30 %.

These pixel groups then defined new potential boundaries, which reproduced to a certain extent the landscape units determined earlier by the means of traditional ecological and geographical analyses (Fig. 6 and Fig. 7). On lowland territories the coincidence with meso-scale regional boundaries was especially remarkable. In all, 73 % of the newly defined boundaries (having a total length of 4500 km) coincided with the buffer zones of meso-scale regions. Our pprevious studies based on fuzzy investigations, resulted average of 5 km wide ökotone (in this region), so this value was used (Mezősi – Bata, 2011). Thus, the boundaries drawn by the new method are verified up to a similar degree.

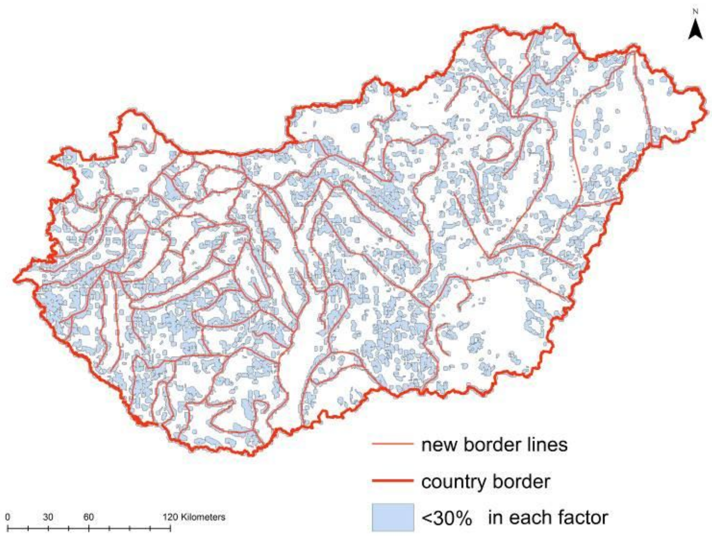

Fig. 6: Boundaries determined by the statistical analysis of the three landscape forming elements, and pixels representing <30 % homogeneity in case of each element.

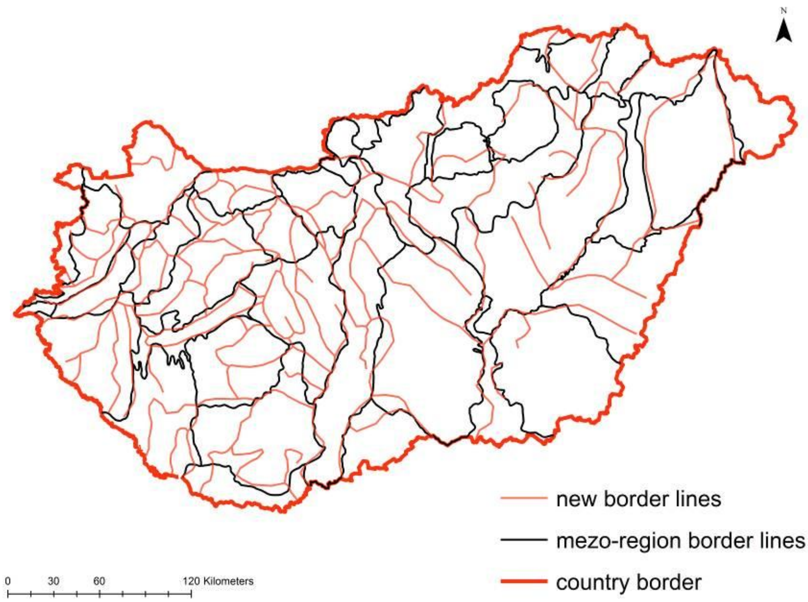

Fig. 7: New GIS based boundaries and the traditional boundaries of geographical meso-regions.

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