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TYPES OF TOPOGRAPHIC MAP GENERALIZATION: THE EXAMPLE OF THE 1: 50 000 MAP*

Abstract: The author first discusses the various ways of classifying cartographic generalization techniques, and then analyzes the course of the generalization process during the creation of a 1:50 000 topographic map on the basis of a 1:10 000 map. Using this analysis as a foundation, the author identifies, discusses and illustrates with examples the five types of cartographic generalization.

Key words: topographic map, map generalization.

Generalization is one of the basic features of cartographic representation. It is carried out so that the scope and the presentation of the content can be more easily perceived by those using the map. At the same time, appropriate generalization should guarantee that the map is a reflection of the spatial variability of the Earth's surface and of the characteristics of the represented objects most important to the map user.

Cartographic generalization is a composite process encompassing the wide range of relations between geographic area (with all its aspects being the subject of investigation in various disciplines) and the great diversity of maps that constitute its reflection. Generalization is a specific, composite set of processes, primarily based on logic and is reflected in the graphic design of the map, which in turn makes possible the correct perception and interpretation of the cartographic image.

Although the problem of cartographic generalization has been investigated for nearly a century and a half (Sydow, 1866), the ways of approaching the problem vary tremendously. Although the nature of generalization is defined

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similarly in each case (selecting the most significant items and deliberately generalizing them), significant discrepancies exist due to the different types of generalization being favored.

In J. Szaflarski's (1965) textbook, the first cartography textbook universally known in Poland, two classical (i.e. formulated in the early 20th century) types of generalization are identified: the quantitative (lower-level) type and the qualitative (synthesizing, higher-level) type. L. Ratajski (1989) identifies the same two basic types of generalization in his textbook, additionally subdividing quanitative generalization into generalization of form of map and generalization of its content, and qualitative generalization into symbolization, grouping and the shifting in the framing of the phenomenon.

In his well-known work, *Semiologie graphique*, J. Bertin (1973) presents an original view of the process of generalization. He identifies conceptual and structural generalization. A similar approach can be seen in J. Kraak's and F. Ormelig's (1998) textbook, where they also identify two types of generalization: graphic and conceptual. In the newest edition of the German textbook by G. Hake, D. Grünreich and L. Meng (2002), two basic generalization types are identified: object generalization (*Objektgeneralisierung*) based on databases; and cartographic generalization, based on maps. These two in turn can both be subdivided into three kinds of generalization: geometric, semantic, and temporal (the generalization of time). The American textbook by A. Robinson, R. Sale and J. Morrison (1988) presents a different approach. Here, four types of generalization – simplification, classification, symbolization and induction – are identified. K. Salishchev (1998) identifies five types of generalization: the selection of the mapped phenomena, the simplification of object outlines, the generalization of quantitative attributes, the generalization of qualitative attributes, and the substitution of separate symbols that stand for individual objects with common signage. Salishchev's expanded and supplemented classification system can be found in the newest textbook written by A.M. Berlant (2001), where eight types of generalization are identified: the generalization of qualitative attributes, the generalization of quantitative attributes, the shift from simple to complex concepts, the selection of objects, the generalization of contours (the geometric side of generalization), the merging of demarcated regions, shifting of the represented objects and exaggeration of the size of objects.

The classification of generalization into so many different types seems to be the result of several factors. The concept of generalization is strictly tied to the nature of the map itself, and since this nature can be conceived in various ways (the map serving as a model, a language, a means of conveying information, or as a database) hence the lack of agreement in the characterization of the processes constituting generalization. Besides, the ways in which generalization is viewed mainly result from the generalization of practical knowledge associated with the creation and utilization of maps. In the face of diversity in cartographic representation, in terms of scale, content, form of representation, and intended use as well, this knowledge is generally limited to relatively few types of maps. Although the generalization process is similar in the case of each type of map, different generalizing procedures are used for each method of representation. Taking into account the various histories of the development of cartography in individual countries or larger geographical areas, what manifests itself by the existence of various so-called "schools of cartography," it is no surprise that a common theory of generalization is yet to be accepted.

In light of all this, it seems that the essence of the process of generalization – the specification of its individual forms and types – is best considered not from a theoretical, but from a practical point of view, incorporating knowledge from the practice of cartography. In addition, the process needs to be appropriate for the specific type of map. This article attempts to analyze and explain the nature of the generalization process used in the creation of topographic maps. The analysis was carried out on the example of the new edition of the topographic map of Poland at the scale of 1:50 000. This map, published in the period from 1995 to 2002 by the Surveyor General of Poland, is largely based on a map at the scale of 1:10 000.

Transforming a 1:10 000 map into a map with one-fifth the scale (while the size of the map itself shrinks 25 times) involves significant generalization. On the basis of map editing guidelines and the analysis of these two maps themselves one can compare the scope of their content as well as the representational techniques used, and be able to define the practical nature of topographic map generalization.

It follows from the analysis that, in the process of designing a mid-scale topographic map, we are dealing with five basic types of generalization, which are at the same time five stages in the generalization process:

1) choosing a categorization system appropriate for the represented objects and classifying them;
2) selecting the objects to be represented within each category;
3) generalizing or eliminating quantitative attributes;
4) replacing of area symbols with point or line symbols;
5) simplifying the outlines of objects.

1. CHOOSING AN APPROPRIATE OBJECT-CATEGORIZATION SYSTEM

As in the case of many other maps, the first stage of generalizing topographic maps involves choosing categories appropriate for the objects to be represented, and by this act classifying the objects.

Compared to the 1:10 000 map, the number of categories on the 1:50 000 map is reduced from 213 to 182, or by 31 (15%). This amount constitutes a balance (of the 45 categories which are not represented and of the 14 new categories with new content which are added) and is the result of various generalization processes taking place at this stage of editing. Five such processes can be identified:

1) *The complete elimination of certain content categories:* Twenty four object categories included on the 1:10 000 map are omitted on the 1:50 000 map. Some examples are: bus stops, meteorological stations, light towers, swimming pools, and deep water wells. Here then generalization involves the elimination of categories composed of objects which are small, hardly significant for orientation and difficult or even impossible to clearly represent on a 1:50 000 map.

2) *The generalization of qualitative attributes* primarily involves replacing symbols signifying the various characteristics of an object with one symbol, representing only the type of object. The following are subject to this type of generalization:

— buildings (on the 1:50 000 map, no distinction is made in the case of multi-family and single family housing, non-residential and high-rise buildings),
— tramlines (no distinction is made between single- and double-track),
— streets (no distinction is made in the case of paved and unpaved),
— tree groves (no distinction is made between coniferous, deciduous and mixed).

3) *The merging of categories represented by separate symbols:* This is what happens whenever objects which on the 1:10 000 map were represented by different symbols, are represented by the same symbol on the 1:50 000 map. For instance, on the 1:50 000 map, one single symbol is used to represent monuments as well as lone graves, and another is used to represent orchards, as well as fruiting shrub plantations and allotment gardens.

Thirteen symbols appearing on the 1:50 000 map do not appear on the 1:10 000 map. This is the effect of generalization also; conceptual generalization in particular (Bertin, 1973).

4) *The substitution of separate symbols with common signage:* This is one of the forms of generalization identified by K.A. Salishchev (1998). On the 1:50 000 map, this is characterized by the introduction of symbols for train stations and stops (in the place of train station buildings and platforms), as well as for dense dwellings areas (instead of the representation of single buildings).

5) *The introduction of symbols referring to general concepts not represented on a map of greater scale:* Another type of procedure is the denotation of content categories representing general concepts not represented in large scale but suitable for representation in smaller scales. Examples of this type of generalization on the 1:50 000 map are the symbols for industrial zone, border crossings and mountain passes. These are not included in the legend of the 1:10 000 map.

2. SELECTING THE OBJECTS TO BE REPRESENTED ON THE MAP

Within the chosen content categories, either all of the objects are represented, or they need to undergo a selection process. The selection process does not apply to objects such as train stations and train stops, bus stations, tunnels, border crossings, administrative boundaries, sewage treatment plants and most classes of roads.

The principles for the selection or elimination of objects represented on the 1:50 000 map are defined with the help of quantitative criteria, but qualitative and mixed criteria are also used, albeit to a much lesser extent.

2.1. QUANTITATIVE CRITERIA

Five quantitative criteria are used: surface area, length, width, depth/elevation and density. The quantitative indicators for the choice are numerical requirements, below which the given topographic object is not represented on the map.

The surface area criterion applies primarily to forms of land use, such as water reservoirs (0.5mm^2), grasslands, wastelands, and sands (10 mm^2).

The criterion of length applies to various objects, such as dikes, breakwaters (2 mm), access roads leading to farms and buildings (2.5 mm), escarpments (3 mm), streams, ridges and embankments (4 mm).

The criterion of width applies only to city parking lots (0.4 mm), train station tracks (0.6 mm), and grasslands (1.5 mm).

The depth/elevation criterion is used quite often. It primarily refers to surface relief formations represented by point symbols, such as glacial boulders, dikes (1 m), pits, embankments and escarpments (2 m).

The density criterion is also often applied and describes – at times only in approximation – the minimum distance between symbols. This criterion refers primarily to line symbols: parallel field and forest roads (4–5 mm), rows of trees, and parallel streams (2 mm).

2.2. QUALITATIVE CRITERIA

Aside from the quantitative criteria, qualitative criteria are also applied in the selection process, though not to the same extent. Three types of qualitative criteria are used on the 1:50 000 map:

— a spatial relationship (of the given object to other objects) criterion,
— a functional criterion,
— a proper name criterion.

The criterion most widely applied is that of the spatial relationship of the given object to neighboring objects. For instance, electric power lines are not drawn alongside railroads and roads nor going through residential areas. Springs and mineral springs are denoted only outside of built-up areas. All rivers that connect lakes together or connect a lake to the sea are represented regardless of their length. The functional criterion is applied primarily in the selection of buildings and minor roads. All pathways constituting recreational trails are represented. Space allowing, residential buildings are shown, followed by government buildings and then industrial production buildings.

The proper name criterion is used as an additional criterion in the selection of springs and waterfalls. Springs and waterfalls are pictured if they have proper names.

2.3. MIXED CRITERIA

In the selection of certain objects, different kinds of criteria are combined. Both quantitative and qualitative criteria are applied.

In the selection of streets, what is taken into account is the space between the streets, as well as how densely it is developed, if at all. Here we can see the merging of the two criteria of density and of spatial relationships.

The selection of government buildings is guided not only by their significance (as for instance when schools are shown while daycare centers are omitted), but also by their size and spatial relationship to other buildings. The factors taken into account in the selection of these buildings are their significance for orientation, stemming from their relatively large size in comparison to the buildings surrounding them, as well as their topographic situation (in the case of freestanding buildings). And so, here the three criteria of function, surface area, and spatial relationships are taken into account.

3. GENERALIZING OR ELIMINATING QUANTITATIVE ATTRIBUTES

In the case of civilian-use maps, quantitative attributes refer primarily to surface relief and, in the case of built elements, are limited to specifying the populations of individual towns. In comparison to the 1:10 000 map, on the 1: 50 000 map, these attributes rarely remain unaltered and most often are generalized (and its accuracy diminished) or is completely eliminated.

The classic example of the generalization of quantitative attributes is the reduction in the number of contour lines on the smaller-scale map, by increasing the interval between them. The vertical distance between the primary contour lines is equal to 5 m on the 1:10 000 map, and to 10 m on the 1: 50 000 map.

The generalization of quantitative attributes is also caused by a less detailed numerical description of objects and points. On the 1:10 000 map, the elevation points are specified to the nearest 0.1 m, and on the 1: 50 000 map to the nearest 1 m. Population figures for towns of 1000 to 10 000 inhabitants are given to the nearest 10 inhabitants on the 1:10 000 map, and to the nearest 100 inhabitants on the 1: 50 000 map.

The elimination of quantitative characterization applies to escarpments, mounds, pits, ridges and dikes. The elevation of these surface relief elements is given on the 1:10 000 map and omitted on the 1: 50 000 map.

4. REPLACING OF AREA SYMBOLS WITH POINT OR LINE SYMBOLS

The use of both area symbolization (illustrating individual object parameters in scale), and point or line symbols is anticipated in the representation of some built and surface relief elements, depending on the size and width of the given objects. The symbols used may be point symbols denoting small objects, or line symbols, representing narrow objects. One can thus talk about scale symbols (area symbols), semi-scale symbols (line symbols), and non-scale symbols (point symbols). One should note that in the case of point symbols we are dealing with the generalization of spatial attributes on two levels. Some symbols, such as the symbols for small bridges, piers, buildings and greenhouses, denote the location of objects (lower generalization level), while other symbols, such as those representing churches or ruined buildings, do not (higher generalization level). The shift from area symbolization on a map of greater scale, to the use of symbols on a smaller-scale map also constitutes a specific type of generalization. Following L. Ratajski (1989), the instance when this shift occurs can be called the generalization threshold.

On the 1: 50 000 topographic map, some content elements are to be represented by a symbol if their measurements fall below a specified lower limit. These measurements include surface area, length and width.

The area limit applies primarily to the denotation of vegetated areas. Forests, tree groves and areas of dense undergrowth are represented by symbols if their actual surface area falls below 1 ha.

Symbols that have a fixed and specified length are used to represent objects shorter than 100 m (tunnels, parking lots), 50 m (bridges, foot-bridges), and 40 m (piers).

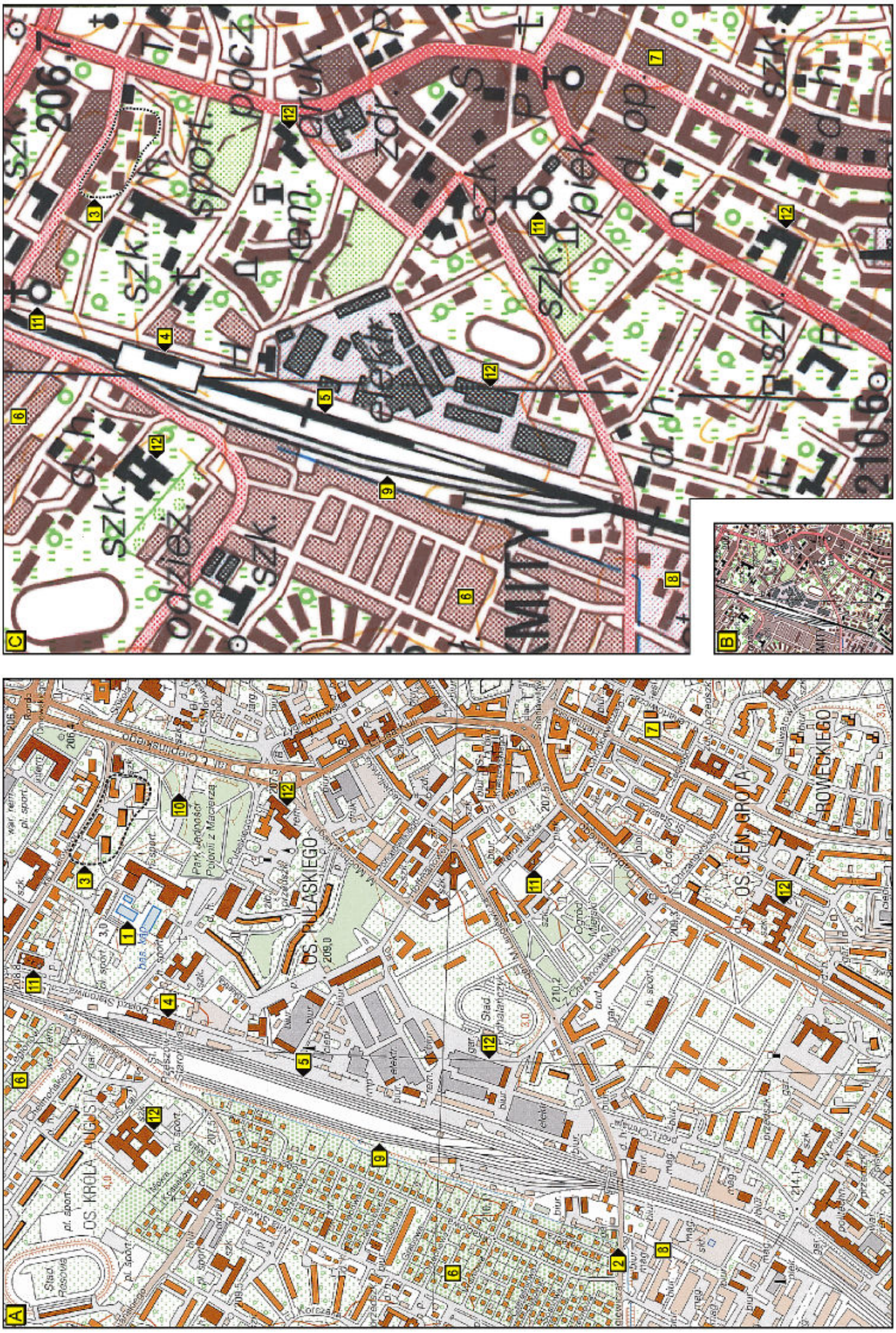
Some line objects are presented in scale if their width is sufficient to warrant legible representation. When the width falls below the specified limit, then a symbol is used instead of a surface area symbol. This limit is 20 m for streets, 25 m for steams, and 30 m for narrow tree groves, as well as for narrow forest and undergrowth areas.

The general rule for the representation of buildings, greenhouses, cemeteries and sewage treatment plants is that a symbol is to be used if the dimensions of the given object (width, length) are equal to or lesser than the dimensions of the symbol.

5. SIMPLIFYING THE OUTLINES OF OBJECTS

The simplification of outlines of the objects presented, an important type of generalization on maps of smaller scale, does not play as significant a role in the scale of 1: 50 000.

This simplification involves eliminating slight breaks in the contours and “holes” within the specified area, merging adjoining areas and, in special cases, exaggerating the size of areas that have a small surface, and the width of areas that are narrow. In the guidelines for editing the 1: 50 000 map (*Zasady redakcji*..., 1998), the rules pertaining to the simplification of outlines are more or less specific with regard to several categories of surface representation:


C
B
A

— breaks in the contours of densely built-up areas cannot be smaller than 0.4 mm, and the width of built-up areas less than 0.6 mm;
— vegetated/cultivated areas covered by the same type of vegetation are to be merged if the distance between them is less than 0.5 mm;
— forest clearings are not shown if their surface area is less than 1 ha (4 mm^2).

The enumeration of these five generalization types and the processes, criteria and principles involved in them is meant to systematize and call attention to the various forms, methods and expressions of generalization on topographic maps. It needs to be emphasized however that the various types of generalization are closely linked to each other and often cannot be separated. For example, substituting separate symbols standing for individual objects with common signage causes the generalization of qualitative characterization, while widening the spacing between contour lines results in the omission of small surface relief formations.

The generalization types discussed above essentially correspond to the successive stages of the generalization process. This is because first we select the object categories to be represented, then we select the objects within each category and, if necessary, generalize their quantitative characterization. Finally, we choose the method of representation (scale or symbol), based on the size of the object to be represented, with objects represented by surface symbols being simplified if their contours are too complicated to render a clear representation. The generalization types identified on the basis of analyzing the 1:50 000 map also occur in the case of topographic maps with other scales (in which case the only changes are in the number of content categories and in the quantitative requirements), as well as general small-scale maps. In the case of the latter, the importance of contour selection and simplification increases, but contour symbols are not substituted by symbols to as great an extent.

Fig. 1. Types of generalization. **A**. A fragment of the 1:10 000 map (Sheet: Rzeszów – Dąbrowski residential area M-34-68-D-d-4). **B**. The same fragment on the 1:50 000 map (Sheet: West Rzeszów M-34-68-D). **C**. A fragment of the 1:50 000 map enlarged to the scale of 1:10 000. Numbers indicate examples of the different types of map generalization from the scale of 1:10 000 to 1:50 000: 1 and 2 – the elimination of content categories (1 – swimming pool, 2 – culvert); 3 – qualitative characterization generalization (single- and multi-family residential and high-rise buildings are represented with the same kind of symbol); 4 – 7 – the substitution of separate object symbols with common signage (4 – a symbol for the train station instead of symbols for station buildings and platforms, 5 – the rail road instead of train station tracks, 6 – a densely built-up single-family residential area instead of emblems for single-family buildings, 7 – a densely built-up multi-family residential area instead of emblems for multi-family buildings); 8 – symbolization representing general concepts not represented on the 1:10 000 map (industrial/storage areas); 9 – object selection within the categories (train station tracks – the criterion of density); 10 – the generalization of quantitative characterization (the elimination of some contour lines); 11 – the substitution of contour symbols with emblems (churches); 12 – the simplification of object outlines (buildings).

The understanding of what exactly is involved in the process of topographic map generalization, its compound nature, how it is expressed and what generalization criteria apply to individual object categories, is essential in attempting to automate the process.

Examples of some of the types of generalization mentioned are illustrated in Figure 1.

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