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Cartographic Design and Production, 2nd edition,
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4 GENERALISATION

As a map is always at a smaller scale than the phenomena it represents, the information it contains must be restricted by what can be presented graphically at map scale. This adjustment process is referred to as generalisation. It applies to all maps, and is fundamental to cartography. In addition to posing a major cartographic problem, it is also a powerful tool, because with generalisation it is possible to make small-scale maps of large areas, yet still selectively include the required information.

All maps are selective, and some highly selective, dealing with only one particular subject in detail. But even within the specified nominal content of a given map, some information will have to be omitted. In addition, complex irregular lines and outlines will have to be simplified. If many features of the same type are in close proximity they may be combined, which in turn can affect the basis of their classification. And because some map elements are judged to be more important than others, they may be visually emphasised, so that the symbols representing them are exaggerated in size, sometimes leading to the displacement of other symbols in the process. These processes – selective omission, simplification, combination, exaggeration and displacement – constitute the application of generalisation to the source information on which the map is based.

In many cases the generalisation processes operate in combination. In a small-scale plan of a built-up area, some individual buildings, usually small ones, may be omitted; the outlines of buildings are simplified; groups of adjacent buildings are combined; and the streets (spaces between buildings) which are retained may be exaggerated in width, leading to the displacement of the buildings fronting on to the street. As a consequence, instead of the concept 'built-up area' being interpreted by the map user from the array of tightly packed buildings, the generalised representation itself is now defined as 'built-up area', thus changing the basis of feature classification. Although details have been omitted, the basic character of the structure of the built-up area will be retained. This can only be done as a matter of judgement, because of the understanding of what the concept 'built-up area' means.

In many cases, especially with small-scale maps, it is impossible to show areal features in accordance with their actual extent on the ground, because they are so small in relation to map scale that they could not be represented legibly. Abstract data, such as height figures, can be included in the map information, even though they have no tangible existence or real dimensions, and yet they must be represented by symbols which are large enough to be perceived. If the information is regarded as important, it is kept in the map by placing a symbol on the location concerned, thereby assigning it a position and describing it by classification. Therefore, its actual dimensions, if it is a real feature, are no longer the basis of either inclusion or representation. This is referred to by some writers as 'symbolisation', but the usage is incorrect, as of course all the information in a map is represented by symbols. The distinctions lie in what aspect of a feature serves as the basis of representation, not whether a mark on the map is or is not a symbol.

FACTORS IN GENERALISATION

Concepts of generalisation

Although generalisation is fundamental to map making, many different views about its scope and function have been expressed, probably because its ramifications are so complex in relation to both information and representation. There is no unanimity on the terms used to describe generalisation processes. A major difference of opinion centres on the question of whether or not generalisation also takes place at the data collection stage, thereby applying to all maps, or whether it is restricted to smaller scale derived maps. Some cartographers adopt the latter view, probably because the generalisation process is obvious with derived maps, and an inevitable cartographic task. The degree of generalisation which has already been applied to larger scale sources is not always evident. Correspondingly, many surveyors seem to believe that as long as linear features and outlines are plotted in their 'true' positions, no generalisation has taken place.

Although virtually all descriptions take into account selective omission and simplification, and recognise the need to maintain graphic legibility, two other factors are often referred to: character or characteristic, and relative importance. A definition given by Hettner (1910/1962) states that 'Cartographic generalisation is altogether something different to what a philosopher means by generalisation. Generalisation is first of all a question of restriction and selection of source material. This is achieved partly by the simplification of features on the map, partly by omitting small or less interesting objects.' This leaves unresolved the problem of deciding 'small' and 'less interesting'. Tobler (1964) indicates the need to '...capture the essential characteristics of a class of objects...' Both Lundqvist (1958) and Robinson (1952) also emphasise 'characteristic' as a fundamental concept in generalisation. The International Cartographic Association *Multilingual Dictionary* attempts a brief definition: 'Selection and simplified representation of detail appropriate to map scale and/or purpose', which again does not clarify 'appropriate' or 'representation'.

If these and other attempts to describe generalisation are analysed, the principal elements referred to seem to fall into two main groups: scale and graphic requirements (legibility), and characteristics and importance. The first pair are determining conditions; the difference in scale between the map and the real world phenomena, or the derived map and the source map, controls the available space, in which there are minimum requirements for graphic legibility. The effects of scale ratio, space and dimensions are in many respects measurable factors. The second pair are essentially judgements; they reflect the need to retain the essential characteristics (in terms of shape and configuration) of the phenomena represented, and also the fact that some things are judged to be more important than others, both within the same general class, and between classes. Therefore, some things will be retained, and exaggerated if necessary, and may be emphasised within the map design.

The exaggeration of symbol size is introduced partly to maintain legibility, and partly to accommodate relative importance. It also affects the map design. A thick line representing a coastline inevitably leads to a greater degree of simplification than a very fine line. But if the coastline is represented in blue, it will need to be thicker than an equivalent black line in order to achieve the level of contrast commensurate with its importance in the total map content and design.

Scale

It is normally true that the smaller the scale of the map, the greater will be the degree of generalisation. Certainly the consequences of generalisation are most evident at small scales. This tends to lead to rather simplistic views which confuse scale with derivation. There are large-scale maps (such as those at 1 : 10 000 scale) which are derived from even larger scale sources; and there are many basic maps at 1 : 50 000, 1 : 100 000 and even 1 : 250 000 scale. It is hardly reasonable to suppose that because a map at 1 : 25 000 scale has been produced from an 'accurate' survey it does not involve generalisation.

All surveys carried out either on the ground or by the interpretation and measurement of aerial photographs require rules for the omission of small features and areas, as well as rules for their classification. This applies to specialised maps, such as geological maps, as well as topographic maps. These rules generally apply to minor features, such as very small streams, areas of vegetation and land use, and small buildings. The detail recorded by the photogrammetric survey is controlled in the first place by the scale and, therefore, the resolution of the photography. The operator has to detect, identify, and then classify features through interpretation.

A comparative study of photogrammetric plotting by several different organisations, using the same photography and the same instructions, shows very clearly that differences in interpretation arise through different operators, and different degrees of generalisation result (Neumaier 1966). The instructions for this comparative exercise state that 'Only those features should be shown which are of importance for the 1 : 100 000 scale map. Features of minor importance should be omitted. In spite of such omissions, the characteristic features of the landscape have to be shown, especially within inhabited areas.' The priority of the relevant factors is summarised as importance, characteristics, and conditions of placing.

If displacement is necessary, the priority sequence is usually as follows: hydrographic lines, railways, main roads, minor roads, buildings, limits of vegetation. Therefore, if the edges of a road are displaced to accommodate a major road symbol, buildings fronting on to the road are displaced accordingly to keep their correct relative positions. Similarly, precepts are given for the treatment of isolated buildings and dispersed settlements.

Because photogrammetric operators can only view a limited area when actually plotting points and lines, it is difficult for them to monitor the relationships between elements over the whole area simultaneously. The possible alternatives are interpretation and generalisation during plotting; interpretation and generalisation before plotting; and generalisation after plotting. These alternatives highlight the fact that generalisation of features has to be adjusted both to their individual symbolisation and their relationships and balance over an area. In all cases, the information that results from the survey is a matter of judgement as well as measurement.

Graphic requirements

It is clear that as scale is decreased, so is the total space available for the map symbols, but these cannot be reduced in proportion, as this would lead to illegibility. Legibility itself depends on symbol size, form and colour, which in turn affect contrast. It is also evident that the total amount of information concentrated within any area can affect the map user, especially if the representation approaches the threshold of discrimination. Cuenin (1972) gives a detailed analysis of the treatment of linear features on maps at a range of scales, comparing actual ground dimensions (width), the sizes of the corresponding symbols at a particular scale, the width which this would represent at ground level, and the corresponding coefficient of enlargement. What is interesting is that this proportional enlargement is not constant for a map at a given scale, but varies with the presumed importance and actual size of the feature. At a scale of 1 : 25 000 a main road is enlarged more than a canal, because the road requires a complex symbol to represent its characteristics and classification, and is also judged to be more important. But a footpath is enlarged by a greater ratio, because the minimum size of legible symbol required is large compared to the width of a footpath.

Apart from the fact that symbol dimensions are important graphic variables, and, therefore, are used to help to distinguish one symbol from another, the purpose of the map and the assumptions about the user's needs and interests also affect the graphic exaggeration. Topographic maps, which place a great deal of emphasis on roads and their classification (in the belief that this information is valuable to the general user), are likely to exaggerate road symbols more than equivalent maps that are not designed under this assumption. Specialised road maps for route planning carry this symbol exaggeration even further. Exaggeration is particularly evident in many illustrative maps, in which the total content is first restricted and then major features emphasised. Therefore, graphic requirements are affected both by judgements of importance and the particular function and style of the map.

Characteristics

The need to retain the characteristics of a feature is often referred to, yet the term is used in different ways. Because the primary information on a map is locational, the linear shape or ground plan of a feature is what the map shows most effectively, within the limits of scale. Roads may be straight or have sharp bends, railways have smooth curves. Coastlines and contours may be smooth or irregular. Some city areas are highly irregular in building shape and layout, others are symmetrical. But the 'shapes' of individual features in this sense are only one aspect of 'characteristic'. Some landscapes are characterised by the frequency of small features; some types of settlement are dispersed, others are nucleated. Thus the character of a geographical feature may reside in its distribution and frequency.

What is characterised can also have a wider connotation. A major road is described not only by its physical dimensions, but also by its hard surface, number of traffic lanes, and its position in a hierarchical classification of roads. Both its physical characteristics and some judgement of its importance will affect the symbol used in its representation, and therefore the degree of exaggeration and possible displacement.

The characteristics of a feature can also be regarded as important because they help to make possible the correct identification and recognition of different features, and reveal essential contrasts and distinctions in a landscape. Identification and recognition are processes of interpretation which require knowledge. So even at very small scales, where generalisation is at its maximum, the retention of characteristic elements demonstrates correctly the differences between features, and facilitates correct interpretation. The definition of what is 'characteristic' is a matter of human judgement or evaluation, helping the map user to place discrete and physically separate objects in the same class, and emphasising differences between them. Probably one of the most difficult cartographic tasks is to carry out selective omission when a region is characterised by numerous small features, either physical or cultural. Linear features can normally be retained by exaggeration if desired, and displacement if necessary. A highly irregular coastline should retain major indentations, and any angularity of form, at small scales, even though the minor irregularities have been removed by simplification.

Importance

The degree of importance attached to a feature will affect both its inclusion and its graphic emphasis. In this respect, emphasis is a consequence of importance. Like characteristics, importance operates at two levels; both in the judgement of relative importance among features in the same class, and the judgement of relative importance between classes. Therefore, a single building may be unimportant in a built-up area, but very important in a sparsely populated one. A small village might be omitted in a densely populated region with many villages, but might be retained if it happened to be the terminus of a road in a rural area. Therefore, assessment of importance can affect selective omission and combination, and frequently leads to exaggeration and displacement.

As most maps are designed to have at least two visual levels, the degree of importance attached to different elements in the map content will lead to a greater graphic emphasis for some, often requiring larger symbols, and therefore more exaggeration. In addition, the basis for classification will change gradually with map scale. What is important on a large-scale map does not necessarily have the same degree of importance on a small-scale map. A large-scale plan of a built-up area does not represent roads by specific symbols, nor does it classify them. A medium-scale map covers a larger area, and is more concerned with routes between places, so a road classification is included, affecting the emphasis of road symbols. At a very small scale, only one class of road may be shown, and the emphasis in selection changes to a limited number of long distance or through routes. In this case, the basis for inclusion is not so much the existence of roads as features, but the function of connection between places shown on the map. In this way, scale, generalisation and map design are all inter-related.

CARTOGRAPHIC SUBJECTIVITY

The practice of generalisation is often described as 'subjective' because individual cartographers use their knowledge and judgement to carry out processes of selective omission, simplification and so on. This is normally contrasted with the scientific principle of attempting to be 'objective', so that individual preferences or prejudices do not influence decisions or experimental results. The description of cartographic generalisation as being subjective is normally stated critically – the implication being that it is a defect that ought to be remedied.

A dictionary definition of subjective gives 'relating to self', and of objective as 'external to the mind'. Whether the external world can be known or understood except through the mind is a question that has perplexed philosophers for centuries. Even so, there is a fundamental contrast between the idea of subjective as being biased, uneven, irrational and incomplete, and therefore erroneous, and objective as systematic, factual, rational, 'scientific', and therefore correct. So far as maps are concerned, it is clear that the locational basis of the map, resulting from measurement and represented in a defined coordinate system, is objective, whereas the description and classification of features on the map is contrived for humanly conceived purposes, and is essentially subjective. Whereas the scale, and to some extent the graphic requirements of legibility are factors that can be treated objectively – that is, they can be described in finite terms – the factors of importance and characteristic are essentially judgements based on interpretation. Once a generalisation has taken place, it can only be described as either good or bad, not right or wrong, because the informational changes introduced have many possible alternatives, and there is no way of defining any absolute solution.

The photographic reduction of a line is objective, in the sense that it operates according to optical laws and is consistent; there is no human interference. But generalisation involves the deliberate changing of the representation to achieve certain ends. There is no absolute standard for generalisation, and indeed whether it is good or bad is also a human judgement. It is at least arguable that there is no such thing as a completely objective generalisation. In practice, the general intent of the objective argument is to make the generalisation process more consistent and systematic, thereby reducing the inconsistency that is inevitable with human operations. The discussion of objective generalisation has been promoted through the development of digital cartography, because for the information to be processed by a computer, specific instructions have to be given. Whereas programs for linear simplification have been devised, the operations involving selective omission, combination, exaggeration and displacement are more difficult to define, and therefore more intractable.

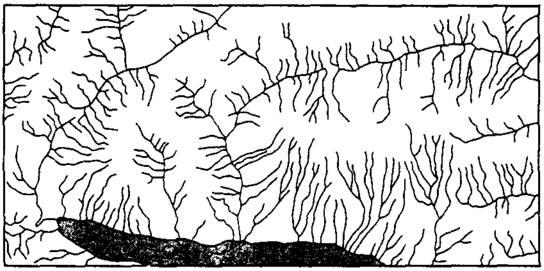
Proper generalisation depends on information and understanding. For topographic features – or at least for those which are a familiar part of the environment – it is generally accepted that their characteristics are sufficiently well known, and therefore do not require special study. Even so, a study of geology, physiography and geomorphology is often included in a cartographic curriculum. A knowledge of vegetation and land use, and of urban and rural geography, is also relevant. It is usually true that it is in the generalisation of less familiar environments that the process is most prone to error, essentially as a consequence of ignorance. To some extent this can be rectified by consulting larger scale topographic maps, but even this requires judgement in interpretation. In other cases, good larger scale source material is simply not available. The official topographic map series of a country, if available, are generally regarded as being the best source for topographic information, on the assumption that the survey organisation will be in the best position to make generalisation judgements about features within its own territory.

For specialised maps, the problems in some ways are more easily defined. Whereas most people are familiar with the features represented on topographic maps, at any scale, the classifications used on a geological map, or a nautical chart, are clearly within the province of specialised knowledge. Therefore, it is essential that any subsequent generalisation of such information should be directed by a specialist who understands both the meaning and significance of the information in detail.

GENERALISATION PROCESSES

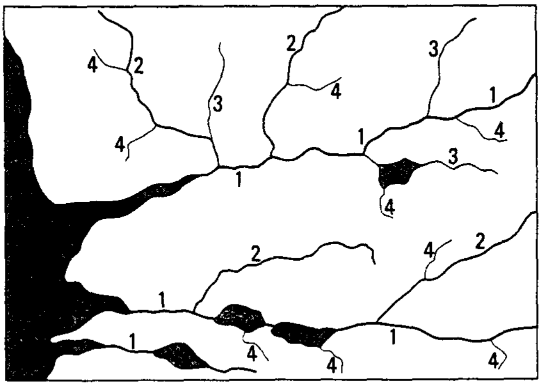
Selective omission

The total number of features in a class, represented by a particular symbol, may or may not be represented in a map. In the case of a small-scale road map, all the major roads will be shown, but many minor roads in built-up areas will have to be omitted. Small topographic features, or small areas in a special-subject map, may be omitted on the grounds that they are unimportant at map scale. The difficulty for the map user – and this is particularly true for medium-scale topographic maps – is that some features are shown while others are not, even though there is a symbol to represent them. An obvious example is the network of drainage channels present in a hilly region, in areas with an abundant rainfall and extensive surface drainage (Fig. 26). On medium-scale maps the inclusion of all of them would lead to a mass of short lines which would provide little useful information, and might interfere with the legibility of other detail. So some are omitted, but some are kept to indicate the general characteristics and distribution of the drainage.



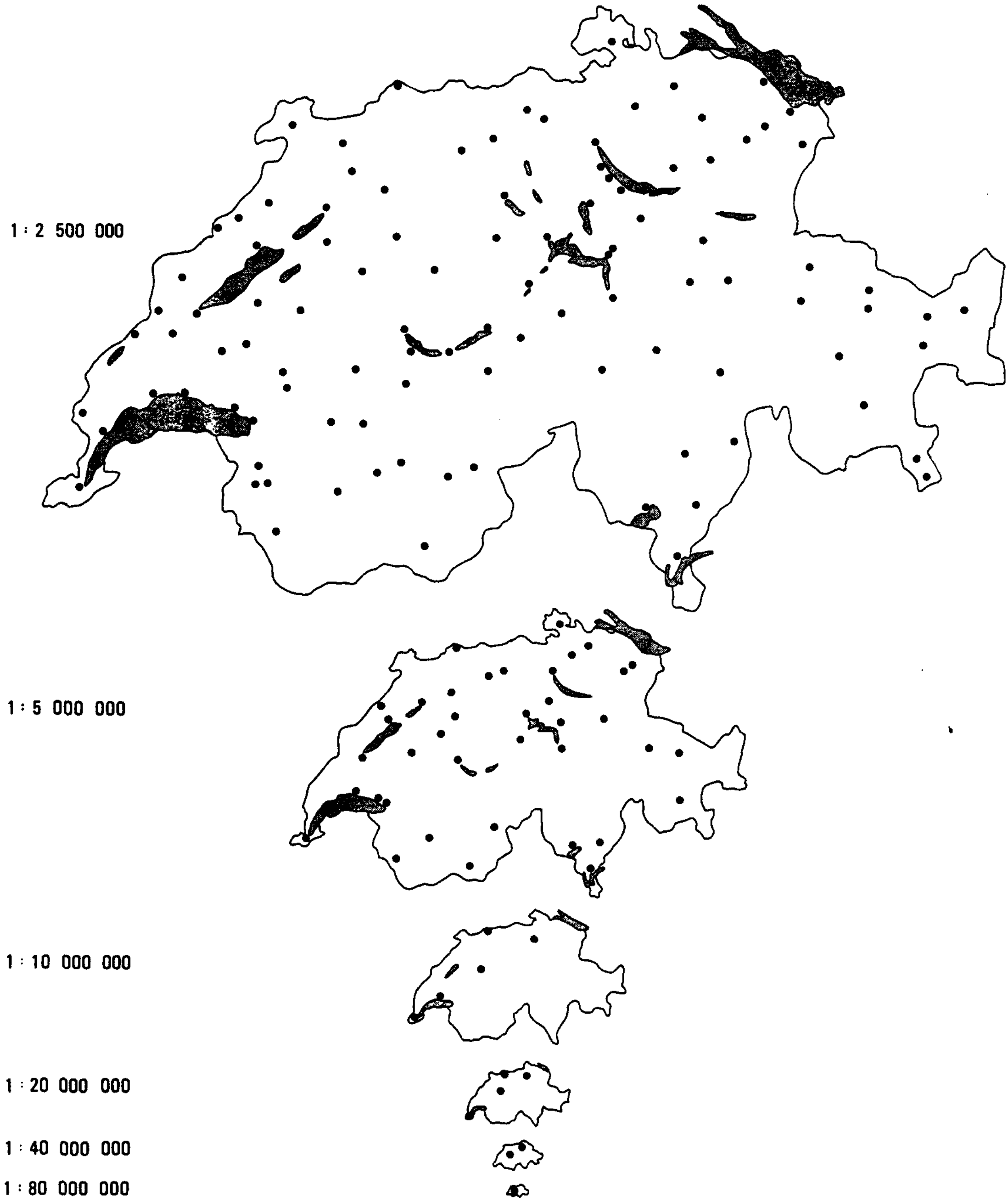
26. Drainage at 1 : 50 000 scale reduced to 1 : 250 000

In normal practice the process operates by first selecting the major drainage lines and tributaries, so that the shape and extent of each drainage basin is correctly indicated (Fig. 27). Smaller streams are added in proportion to their frequency in different areas. At the initial stage, length of stream may be the first factor to consider, the larger ones taking



27. Priorities in selective omission priority in the selection. But in the final adjustment, short streams which form part of the interconnections in a drainage system are also included, in order to complete the drainage network. Thus the judgement of relative importance is not simply a matter of size, but of local significance. The major problem with selective omission is that it can be applied consistently over large areas, but varies locally. In the same way, isolated small buildings are retained as landmarks, even though buildings of the same type and size would be omitted in built-up areas.

The progressive effect of selective omission of settlements at small scales is illustrated by Fig. 28.



28. Progressive elimination of settlements at small scales

Not surprisingly, attempts have been made to make the process of selective omission more consistent, or more rational. These can be said to fall into two main groups: specific 'rules' that are said to govern the process by a quantitative decrease in information with scale; and methods that use extra information to judge relative significance.

Rules for selective omission

It is clear that if a map is being compiled from a larger scale source map, then normally only a proportion of the features shown by individual symbols for one category will be retained on the derived map. The problem is to determine the ratio between the number of objects on the source map and the number retained on the derived map, and to take into account the factors which influence this. The relationship is clearly based on the scales of the two maps, and therefore their respective areas.

Cuenin (1972) points out that this process is considerably affected by scale. Using the terminology that

N_i = number of objects on the source map, scale $1 : M_i$
N_f = number of objects on the derived map, scale $1 : M_f$

then if there is a very small scale difference between the two, all the objects may be retained, so that $N_f = N_i$. This is more likely to occur at large scales, for example if a map at 1 : 5000 is derived from a source map at 1 : 2500.

If the same density of objects is to be retained on the derived map, then this is obviously a function of the relative areas of the two maps. This can be expressed by

$$N_f = N_i \left(\frac{M_i}{M_f}\right)^2$$

in which the number of objects retained is inversely proportional to the square of the scale relationship.

Cuenin (1972) then goes on to show that if the scales of the derived map and the source map are in the ratio of 1 : 2, then the proportion of objects retained on the derived map can be controlled by adjusting the equation.

If 70% are retained, then $N_f = N_i \sqrt{\frac{M_1}{M_f}}$

If 50% are retained, then

$$N_f = N_i \sqrt{\left(\frac{M_i}{M_f}\right)^2} = N_i \left(\frac{M_i}{M_f}\right)$$

And if 25% are retained, then

$$N_f = N_i \left(\frac{M_i}{M_f}\right)^2$$

With greater scale differences, then

$N_f = N_i \sqrt{\frac{M_i}{M_f}}$ is more common.

At small scales, usually less then 1 : 1 million, the relationship is complicated by the fact that the symbols used to represent the objects will already have been exaggerated, and that the symbols included in the derived map may also differ in size from those on the source map. To account for this, Töpfer and Pillewizer (translated with a critical commentary by Maling 1966), introduced two additional factors: a constant for symbolic exaggeration (C_b), and a constant of symbolic form (C_z).

These 'rules' are a rationalisation based on the examination of existing maps. Although they could be used to check a process of selective omission, to see if it was in accordance with what should be expected with a given map type and scale reduction, of course they do not explain which of the objects on the source map should be retained.

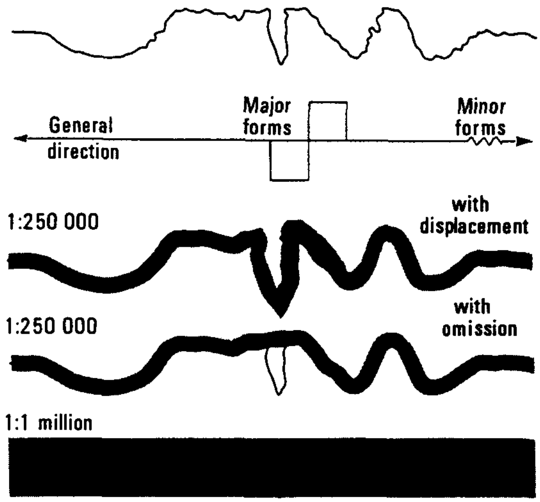
The operation of the rules has been demonstrated with both point and linear symbols. In both cases, poor selection may still lead to a poor generalisation, even if the quantitative rule has been followed.

Factors in relative importance

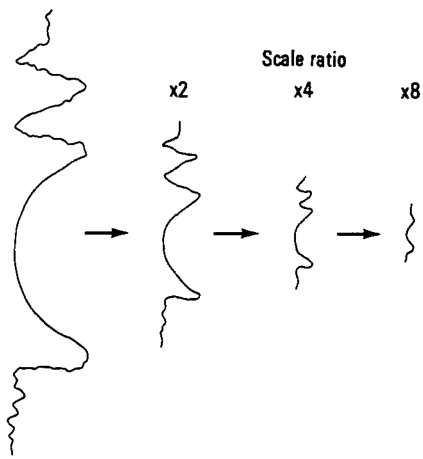
The second approach is closer to the process of selective omission in the operational sense. Taking the example of the selection of named settlements on a small-scale map, it is clear that several factors are taken into account in deciding which to include and which to omit in a derived map. The selective omission is based on the judgement of relative importance. Major towns do not pose any problem, as they have a high priority in the total map content. But in a densely populated region there are usually many small towns and villages of much the same apparent size. Indeed, if a small-scale map is the source, they are all likely to be included in one classification, and represented by one symbol. Some of these may be selected by topographic factors that can be interpreted directly from the other map information: for example, position at a bridging point on a river; at the head of navigation; at the junction of several important routes; at the terminus of a route.

Other factors could be introduced on the basis of external information, such as political, cultural or economic significance (Stenhouse 1979). This information may be available to the cartographer through his own knowledge and understanding, but this is unlikely to be consistent over large areas. But this type of information could be systematically compiled from other reference sources, and then used to provide a basis for selection. Given sufficient information, it could also be specifically directed in relation to the type of map. For example, in a tourist map, cultural, recreational and transport and communication information would have a greater effect on selection, and could be given a higher priority. If all the places were listed from a large-scale source in a small data base, and these factors assessed and then given a numerical rating, selections of places could be extracted according to defined factors, which in turn could be used as a basis for inclusion. It is the sort of task which could be dealt with relatively easily with a computer, as the total amount of data could be quite small, and the processing simple. For such a tourist map, all the towns which had any rating on the tourist scale of cultural interest would be automatically selected, and given priority over similar towns which did not have such a rating.

This type of procedure underlines one important fact in the cartographic treatment of information. In many cases the generalisation could be improved by additional input, by simply expending more time and effort on obtaining information, especially from non-map sources. The more rational treatment of some generalisation processes is fundamentally dependent on this.



29. Simplification of an irregular line



30. Effect of line reduction

Simplification

Simplification applies both to linear features and the outlines of areas. The greater the sinuosity of the line, the greater is the effect of simplification. A straight line reduced in scale will still be a straight line, although shorter. A highly irregular line will suffer a progressive diminution in length as its minor irregularities are removed. Therefore, during this reduction it is very important that the characteristics of the feature concerned are retained. What has to be avoided is the replacement of irregular lines by smooth curves, and to avoid this exaggeration may have to be introduced in some cases.

If a section of irregular line is considered (Fig. 29), it can be described as having three main elements: its general direction, major forms and minor forms. The major forms are marked by a sharp change in angle, and sufficient length of segment to make this noticeable. Simplification will lead eventually to the removal of the minor forms entirely, but the major forms should be retained as far as possible. Eventually, at a very small scale, only the major direction will be retained. Generalisation, therefore, progressively reduces irregular lines to regular ones, consisting of sections of straight lines or arcs (Fig. 30).

Where lines show complex features, such as coastlines, the retention of both major and minor forms also depends on the separation or spacing between adjacent line sections (Fig. 29). At some point a decision has to be made as to whether a particular space should be retained by exaggeration, or omitted. In order to maintain the major forms, it may be necessary to displace the lines slightly, so retaining the feature.

In practice, the omission of minor forms tends to happen automatically as the corresponding increase in line width with smaller scales reaches the point where the irregularities are smaller than the line dimension. If the major forms are angular, and marked by abrupt changes in direction, these should be kept, as otherwise the line character is lost.

The analysis of simplification

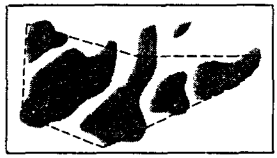
During the simplification process, a cartographer can scan a section of line, and can change from concentrating on minor details to major forms at will, and can perceive a whole section of line simultaneously. Therefore, the operation of simplification can respond both to the detail of the line section and the overall line direction. In generalisation using digital data, the computer can only 'scan' the line data serially. It can be programmed to inspect a section of line several points ahead, and then ignore any changes in direction which are less than a certain angle and length. But it is difficult to make fixed rules about the extent of detail reduction. The cartographer can adjust the simplification to take into account the local characteristics, and consider the relationship of the line with other lines in the composition.

Line simplification using digital data and digital processing has been examined at length in many experimental studies, and several algorithms exist to perform line simplification (see Muller 1987). It is affected both by the nature of the original digitising and its subsequent processing. Small-scale line simplification is well illustrated by Pannekoek (1962), whereas McMaster (1986) and White (1985) deal specifically with data processing.

Combination, exaggeration and displacement

Where many features of the same type are in close proximity, selective omission and simplification are often accompanied by combination, exaggeration and displacement. Whereas a large-scale map will show all areas of woodland above a certain minimum size, a small-scale derived map will omit small isolated areas, and group together adjacent areas into a continuous whole. So the small spaces are omitted and the general outline simplified (Fig. 31).

The effect is particularly noticeable in the



31. Combination

generalisation of built-up areas. Figure 32 shows how the building outlines on a large-scale plan would become quite illegible with a scale reduction of 25 times, and demonstrates the degree of generalisation needed to maintain a legible image. As the scale is reduced, the buildings are progressively grouped into blocks, major roads are exaggerated and minor ones omitted, until eventually all that is retained is a major road surrounded by continuous buildings.

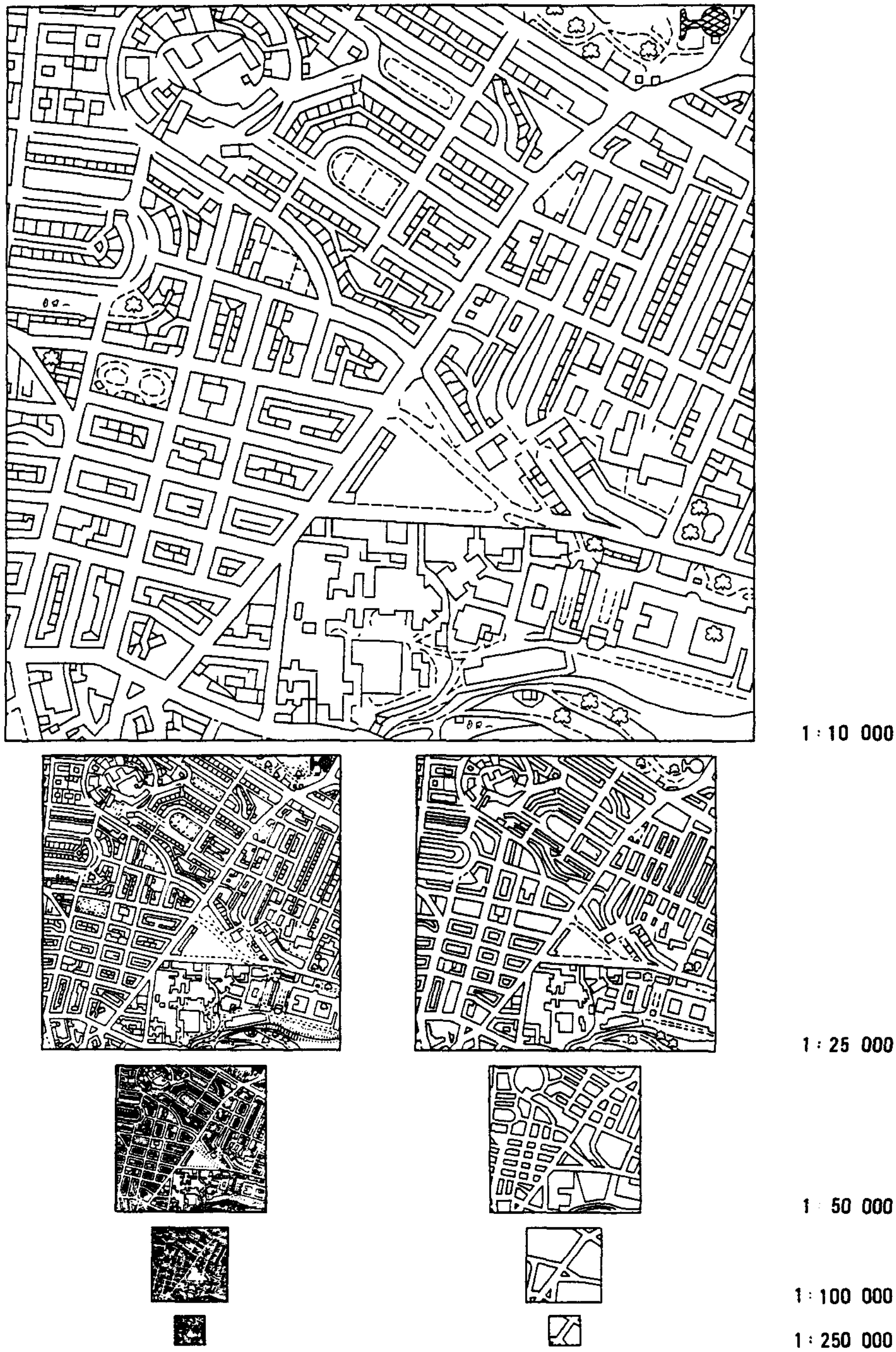
Compared with line simplification, the generalisation of built-up areas is complex. This is revealed by the work of Christ (1976), in which the built-up areas on a topographic map at 1 : 50 000 scale were digitally generalised for a derived map at 1 : 200 000 scale.

The combination of features of the same type can only take place on the basis that their extension over the intervening 'spaces' is theoretically possible. Therefore, this type of combination cannot be applied to islands, which would convert water into land.

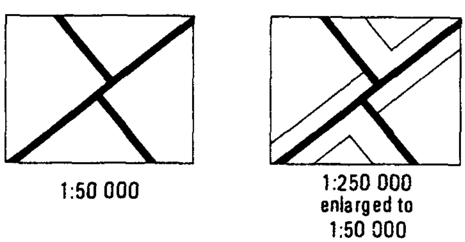
Linear features which are close together will still need to be represented by legible symbols at small scale, and a point can be reached when it is impossible to place the linear symbols side by side without displacing them to intrude into a larger area. If a river, canal, railway and road lie in close proximity in a narrow valley, then the symbols necessary to represent them legibly at a smaller scale may occupy more level space than actually exists on the derived map. In this case the contours which delimit the plain may also have to be adjusted, so that the linear features are not moved on to a slope.

At large and medium scale, where planimetric position of measured points (such as triangulation points) is important, linear features may have to be displaced in order to keep the measured points in their correct positions (see Christ 1978).

Displacement also occurs when small differences in position are important to the map user. A typical example is offset road junctions (Fig. 33). The relative positions of the minor roads may have to be exaggerated and displaced at small scale, in order to make this clear.



32. Comparison of photographic reduction and generalisation



33. Exaggeration and displacement of linear features

THE PRACTICE OF GENERALISATION

The source material used for a derived map is normally at a larger scale, and sometimes a very much larger scale, so that the generalisation processes involved during compilation of the new map must anticipate the effect of reduction. The task can be approached in two ways. Generalisation can be carried out at the scale of the source map, and then reduced to the desired scale, or the source material can be reduced to the smaller scale and the generalisation processes carried out subsequently.

There are advantages and disadvantages with both methods. Working at the source scale gives a clearer picture of all the detail, and if the map is complex this can be important. If only a limited amount of information is required from a particular source map, then this can be extracted and the unwanted information omitted. The cartographer must anticipate the effect of scale reduction. Working at the reduced scale helps the cartographer to produce a generalisation that is appropriate to the derived map, but a photographic reduction of the source map may be difficult to interpret correctly, increasing the risk of introduced errors.

With the first method, it is essential that the line widths on the compilation for the different linear features and outlines are enlarged in proportion to the scale difference. If the source map is at 1 : 50 000 scale and the derived map at 1 : 250 000 scale (a scale difference of five times), then the lines used on the compilation should be five times as wide as the specified symbols. This will ensure that the minimum degree of simplification will be achieved, and will make clear where any displacement is needed to retain feature characteristics.

Because on a very small-scale map there is often little space to include important features in highly developed areas, it can be difficult to resist adding more information in areas where space permits. This will lead to an unbalanced generalisation, by applying different criteria in different parts of the map.

Sequence of operations

As the generalisation of one element will affect the generalisation of others, it is necessary to follow the correct sequence in procedure. The basic topographic information is dealt with first. As the locations of many cultural features are relative to physical features, the generalisation of the physical features is the first task. The usual order is hydrographic features (shorelines and drainage), followed by contours and heights. Modifications to shorelines and drainage channels have to be followed where necessary by other terrain features. Locations of places on, or near to, water, will then be relatively correct on the derived map. Changes to the relief information will in turn affect those cultural features that are defined or influenced by the topography. For example, a boundary may be defined partly by following a river, and partly by following a watershed. Its position therefore moves in accordance with the generalisation of those features.

On small-scale maps, where many settlements may be indicated by point symbols, these must be placed in correct relationship to the terrain. Features that are connected to inhabited places, such as roads, tracks and paths, should be dealt with either after or in combination with the generalisation of settlements. Areas of vegetation and land use, which in developed regions are usually delimited by fences, roads, and other topographic features, are usually dealt with last, as their outlines depend on the positioning of both physical and cultural features. At large and medium scales, many minor internal boundaries are positioned in relation to surface features, including roads, streams and fences, and can only be compiled when the rest of the information is complete.

Features represented by point symbols, such as individual buildings, have to be placed in correct relationship to the topography. A water mill must remain adjacent to the stream, and therefore must be positioned in accordance with the course of the stream as it appears on the derived map. If a building lies between a river bank and a road, it must keep this position. Houses fronting on to a road must remain aligned on the road edge, displacing them if necessary to accommodate the larger road symbol.

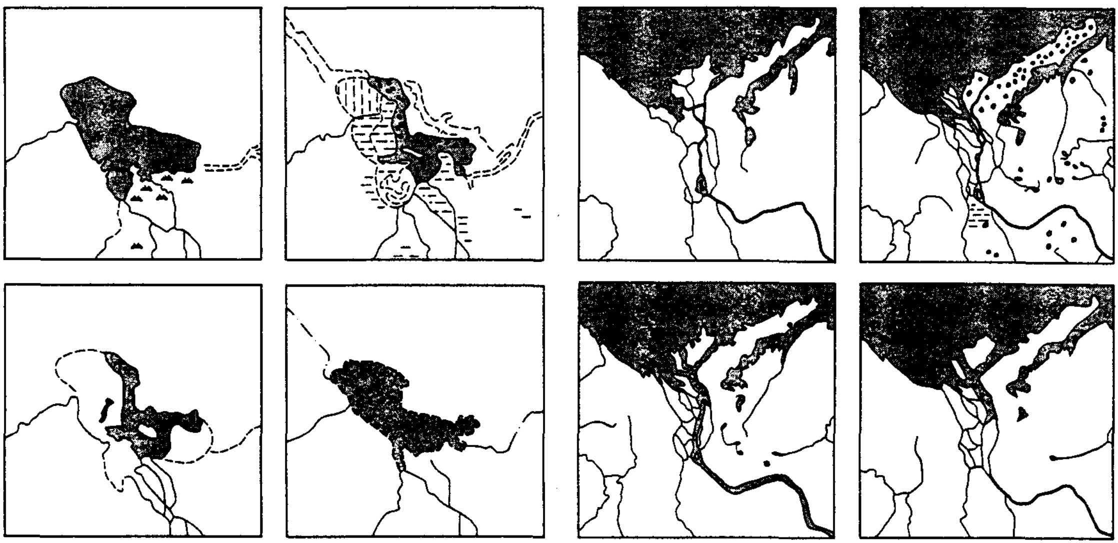
Consistency

Consistency in treatment is most difficult to achieve if a map is derived from several different source maps, especially if these themselves are at different scales. The generalisation of common features is likely to be different in detail on the different source maps, particularly with regard to selective omission. If a road taken from one map does not fit the topography as shown on another map, then the road alignment must be brought into agreement with the topography. Highly detailed boundary lines should not be added to a map where the treatment of the relief is very simplified.

With specialised maps, a major difficulty can be the different degree of generalisation between base map information and special information. Simple choropleth maps, which make very generalised statements, should not be shown with detailed topographic bases. A detailed topographic base, including outlines of major terrain and boundary features, may suggest a degree of specific detail quite out of keeping with the nature of the subject matter. Thus consistency requires above all an understanding of the nature and quality of the source material, and the characteristics of the features or phenomena being represented.

Successive generalisations can lead to a gradual reduction in the overall quality of the information, and the validity of its correspondence with the features and phenomena represented. Very small-scale maps are composed by the generalisation of other small-scale maps, and this re-generalisation process tends to repeat or even exaggerate errors once they have been introduced.

Figure 34 shows two examples of different generalisations of the same area, taken from four different maps. The variations are almost certainly due to a combination of different source material and successive generalisations by different cartographers. It is also clear that the cartographers concerned had different views about the level of detail proper to a given scale of representation. They demonstrate that, whenever possible, an effort should be made to return to much larger scale source material, especially the small-scale topographic series produced by national surveys, so that the fundamental topographic configuration – coastlines, major rivers, islands – is rectified where necessary.



34. Different generalisations of the same geographical area