Cartographic Generalization: The History and Evolution of a Fundamental Subject

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Generalization concepts and operations are such a fundamental part of modern cartography, it is somewhat of a surprise to realize that, despite the long history of map-making, such notions are relatively recent. Or, perhaps we should say, the articulation and intellectualizing of them is relatively recent. Implicit understanding of the fact, that scale reduction affects the amount and form of the data that can be shown on a map, must have existed for a long time. However, taking this to the explicit level, both conceptually and quantitatively, of "how, why, when and which", is only an early modern phenomenon.

Thus, trying to explain generalization as an inescapable process, which should be treated systematically within the practical business of design and compilation, seems not to have taken place until the late 18th century. When it did occur, it was, at least in the Western tradition, part of the intellectual ground swell which led to the very notion of "cartography" itself. That is, one of many elements in the accelerated gathering together of ideas about the scope of map-making that provided the critical mass for Santarem to enunciate his definition of cartography in the early 19th century: a watershed point noted later in Wolter's "Emergence of a Discipline" thesis.

Nevertheless, in the early stages, the symbiosis of scale-and-information was intuited rather than identified. Initially, it even lacked a name to characterize it an fundamental process. Neumann has indicated that, etymologically, "generalization" seems to have arisen in French, circa 1600, via Latin, and spread, thereafter, to other Western languages. In English, the Oxford English Dictionary, dates it to 1761. In it's original coining; derived, it seems, in the expanded vocabulary contingent upon increased knowledge exchange during the Enlightenment ; it denoted, "a broadening out", and it remains, in everyday language, much the same today. Curiously, in its transfer to cartography, the term simultaneously implies, the idea of a narrowing down; in the sense of summarization and, therefore, omission of detail.

As such, probably the earliest attempt, in a Western language, at indicating that the underlying logic needed practical exposition is Müller's "Theoretisch-praktische" text of 1778. This, to a large extent, provided a commentary on the experiences of land-surveyors, who measured at one scale but compiled at a smaller one. It was followed by a number of practical mapping texts which provided "rules of thumb" and broadly based comments on the need for care in depicting terrain and human data appropriate to the scale.

Attempting to formulate the first tentative quantitative statements about the process, took over another hundred years. It was preceded by a growing awareness of the need for careful organization, summary and depiction of data at a wide variety of scales. This extension of concern, from mapping at comparatively large scales to mapping at medium and small scales, and, hence implying a hypothetical comparative range over *all* scales was, for example, consistently remarked upon by Sydow in a number of articles in *Petermanns Mitteilungen* in the 1850's and 1860's.

At the end of the 19th century, the first steps in moving considerations from the qualitative to the quantitative started to take place. As befits a widely situated discipline, some of this took place outside cartography. Thus, the philosopher Josiah Royce saw, as others have since, the map as an exemplar of reason and, thereby, connected logic and its mathematical form and flexibility together. The geomorphologist, Albrecht Penck, in investigating the map depiction of the Istrian coast at various scales, came to realize that a graphical plot of derived coastal length led to a systematic reduction of values; suggesting, very strongly, that formulae might be constructed for successive generalization steps.

Alfred Hettner then took this a stage further by suggesting simple mathematical ratios relating scale values giving general guidelines for consistency in data treatment were possible. Even so, the pioneer efforts of the few investigators remained in intellectual limbo for a long time. Most informed cartographic commentary in the first half of the 20th century; for example, that of Max Eckert; was of the narrative kind; i.e., useful, but lacking precise structure.

What changed everything was the advent of the computer. The promise of digital operations gave new life to generalization thinking. Most significant among those who developed comprehensive new lines of approach was Friedrich Töpfer. His work was brought to the attention of English-speaking readers by Maling, in 1966, and has formed the basis of a number of useful investigations. See, for example, among others, the investigations of Steward, Rusak-Mazur, Rebert and Zhou, cited below. However, the existence and implications of Töpfer's main work; that is, his summary text, *Kartographische Generalisierung*; has been all but ignored in the general cartographic arena. Similarly, the possibility of extensions to his work by the use of other related quantitative approaches; for example, fractal theory, Horton's fluvial ordering scheme, Srnka's re-interpretation of the Radical Law, the work of Perkal, Crofton and other mathematicians, Richardson's contiguity commentaries, and so on; remain only at the fringes of consideration.

Today, at the beginning of the 21st century CE., automated generalization operations tend to very specific, applying to particular phenomena, particular scales, particular data-processing needs, and so on, rather than being ultra-broad in scope, multi-layered or explicable in terms of complex inter-scale connections. In addition, or because of this, the thinking about generalization tends very much to the computational, rather than the somewhat different, and wider, concerns of the visual or the geographical. This emphasis, it should be said, occurs despite "visualization" concerns and the "G" in GIs and, in some ways, is a particular view on information construed as data alone, rather than data-plus-meaning.

This is not to decry the many skillful investigations which have, and are still are taking place, nor to suggest that the core idea of early researchers; i.e., completely automated generalization; should be reintroduced as an emphasized concern in current research. The early achievement of any meat-system latter has clearly been placed in abeyance by the growth and capability of interactive systems. If it does re-emerge, it would seem likely to happen, as a byproduct of the continued growth in the sophistication and computing power of both hardware and software systems: a process, as it were, of "natural" technological evolution.

What would seem to be a desirable adjunct to this powerful ability to illustrate the phenomena of the world, is an ability to understand the inner nature of generalization. This is a tall order. Any overarching theory would have to combine many complex interactions and take note of map intentions, audience, and so on. It is here, that the work of Töpfer may prove of great benefit, not only for particular data-sets but also for their integration at topographic and chorographic scales. What follows is an indication of the power and possibility of extending his "Principles of Selection" as a next step in the historical process.

Selected References

Eckert, Max, (1908), "On the Nature of Maps and Map Logic", **Bulletin of the American Geographical Society**, 40, 6, pp. 344-351. Translated from the German by W. Joerg.

Eckert, Max, (1921), "Das Generalisieren" in his, **Die Kartenwissenschaft**, Vol. I, de Gruyter, Berlin, pp. 328-339.

Fahey, Larry (1954), **Generalization as applied to Cartography**, MA Ohio State University, x, 80 pp.

Hettner, Alfred, (1962), "Die Eigenschaften und Methoden der kartographischen Darstellung", **International Yearbook of Cartography**, Volume 2, pp. 13-35. A reprint of his 1910 exposition on "Characteristics and Methods of Cartographic Representation".

Müller, F.C., (1778), **Theoretisch-praktische Abhandlung über das richtige Aufnehmen und Zeichnen der Situationscharten nach blossem Augenmasse**, Munster.

Neumann, J., (1972), **Genesis and Definition of the term "Cartographic Generalisation"**, paper presented at the 5th ICA Technical Conference, Montréal/Ottawa, 9 pp.

Penck, A., (1894), **Morphologie der Erdoberfläche**, 2 volumes, Stuttgart.

Rebert, Paula, (1988), **Raster-Mode Generalization of Land Use/Land Cover Maps**, MS., Northern Illinois University, De Kalb, Illinois, viii, 175 pp.

Royce, Josiah, (1901), "First Illustration of a Self-representative System", in the Supplementary Essay to Volume I of his, **The World and the Individual,** Macmillan, New York, pp. 502-512 and ibid.

Rusak-Mazur, Ela, (1988), **Objective Generalization of River Networks in Small Scale Reference Maps: Using Horton's Ordering Scheme and Töpfer's Radical Law**, M.A., Queens University, Kingston, Ontario, ix, 100 pp.

Rusak-Mazur, Ela and Castner, Henry, (1990), Hortons Ordering Scheme and the Generalisation of River Networks", **Cartographic Journal**, 27, 2, pp. 104-112.

Srnka, Erhart, (1968), **The Regularities of Cartographic Generalization - Their Analytical Derivation**, Report to the ICA, India, 25 pp. Conference, Delhi

Steward, H.J., (1966), **A Sample Study of the Selection of Populated Places for Inclusion on Atlas Maps**, Dissertation for Postgraduate Diploma in Cartography, University College of Swansea, Swansea, Wales, v, 53 pp.

Steward, H.J., (1972), **Cartographic Generalisation: Some Aspects of the Automation Problem**, Ph.D., University of Wales, Swansea, Wales.

Steward, H.J., (1974), "Cartographic Generalisation: Some Concepts and Explanation", **Cartographica,** Monograph, No. 10, 77 pp.

Taketa, Richard Akira, (1979), **Structure and Meaning in Map Generalization**, Ph.D., University of Washington, vii, 209 pp.

Töpfer, Friedrich (1974), **Kartographische Generalisierung**, Ergänzungsheft Nr. 276 zu Petermanns Geographischen Mitteilungen, Hermann Haack, Geographisch-Kartographische Anstalt Gotha/Leipzig, 336 pp.

Töpfer, Friedrich and Pillewizer, W., (1964), "Das Auswahlgesetz, ein Mittel zur Kartographische Generalisierung", **Kartographische Nachrichten**, 14, 4, pp. 17-21.

Töpfer, Friedrich and Pillewizer, W., (1966), "The Principles of Selection", **Cartographic Journal**, 3, 1, June, pp. 10-16. English version of Töpfer and Pillewizer (1964), cited above. Translated with expanded commentary by Derek H. Maling.

Wolter, John, (1975), **The Emerging Discipline of Cartography**, Ph.D., University of Minnesota, xii, 345 pp.

Zhou, Yu, (1993), **The Effects of Scale Change on Map Structure**, Ph.D., Clark University, Worcester, Massachusetts, xii, 268 pp.