Thematic Cartography and Transformations
To Waldo Tobler

who developed the concept of transformation
and opened up for us so many new paths in cartography

To Henri Reymond

who helped us put these new paths to work,
offering guidance and scientific support to our reasoning

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In any scientific study the work is done on three levels: declaration of a guiding idea, conception of suitable methods for verifying it and use of techniques to implement these methods. This book is intended to be devoted to the methods of working with localized information, and as such is it somewhat of a scientific paradox. How can we use the rich range of techniques which the authors present to us without first posing a problem or a hypothesis?

This question can be inverted: how can a researcher in the Earth Sciences conceive a project without knowing whether the tools which may help with it already exist? The authors start from the idea that tools are a determining factor in a good part of geographical research and that the most important of these tools is a so-called thematic map. The map allows us to pass from a literary (linear) description to two- \((x,y)\), three- \((x,y,z)\) or multidimensional descriptions which are irreplaceable when trying to learn about the surface of the globe.

Maps whose theme is not topographic are traditionally qualified as “thematic”. The theme can be anything from relief forms to the distribution of lovers of quiche Lorraine. The authors of this book are interested in variables (quantitative) or characters (qualitative) of terrestrial phenomena which may be socio-economic or natural. Only indirectly do they address mathematical cartography, which treats, in particular, projections onto ellipsoids [DON 95]. We will see below that the authors are interested in the differences found in methods which have to do less with the themes than with their discrete or continuous character.

If the map is crucial for research, it is not only because the map facilitates observations on a plane, but also because, depending on the method adopted, it may bias or even completely falsify the researcher’s interpretation. Taken to the extreme, if a user does not know how the map’s legend was designed, he or she will not be able to interpret it at all. It is also common that a person unfamiliar with the data-
structuring methods produces maps which are not comparable to others, difficult to read, not very objective or even prejudiced. For this reason, some regional studies, although based on cartographic representations coming from reliable censuses in administrative units, appeared as mere artifacts. The regional grouping in them seemed to be the result of slicing done in a premeditated fashion. Since researchers or administrations cannot justify the logic of their slicing, they could be suspected of demonstrating the regional hypothesis which they expected to see, simply by choosing the boundaries in the way that suited them yet without altering the data in any way. Instead of a guiding principle it becomes more like rough guess work. It is, therefore, with a good reason that the authors of this book insist on the rigor of the methods of grouping values into class in other words on “discretization”. Even though the discretization of values centered at the mean and normalized by their standard deviation is widely used nowadays, it is still useful, necessary in fact, to remind the reader of it as well as to compare it with other methods.

Discretization is also spatial: administrative units (cantons, departments etc.) are examples of partitioning observations. In these examples a country’s area is divided into irregular shapes, mostly reflecting political considerations (electoral districts, school maps, plans of land use, and others, which generally aim at reducing the effect of the dominant populations). Alternatively, the divisions may be based on long distant and forgotten historical heritage. Their shape is often “not very geographic”. We need, therefore, to try to reduce the influence of the shapes and sizes of units which makes the data contained in them impossible to compare. To this end we can either work with the data (for example, the data can be weighted by unit area and thus become a relative quantity) or with the spatial units (for example, by adopting a lattice). Geography is thought of as a science of spatial relations, so that the comparability of the observations is a prerequisite for finding the relations among them.

Unfortunately, discretization of the units (the containers) and the values (the content) is a convenience which goes against the very nature of the Earth: the surface of our planet is continuous. The break between the sand and the water on a sea shore is only an illusion: the continuous rocky relief under the surface of the ocean is smooth, albeit deformed. Similarly, the temperature never falls suddenly as soon as a political border is crossed, not even during the Cold War. Thus, we need to employ a variety of methods and special techniques: isolines and points of variable density are suitable. The construction of isolines, however, involves choosing an appropriate interpolation method. Thus, we arrive at geostatistics.

This brings us to another distinction: while the treatment of variables makes use of methods (standardization, interpolations, etc.), their graphical expression makes use of procedures (shaded choropleth maps, isolines, proportional symbols, etc.).
These techniques themselves will become an object of semiotics which the authors also consider.

It will become clear that thematic cartography has become inseparable from statistical methods. Not only do statistics guarantee a certain degree of objectivity in the data structure, but coupled with computer science they also enable us to process large quantities of data. It is obviously impossible to process a remote sensing image containing seven million pixels in each of its channels, either manually or intuitively.

After all, what is data? It is an observation which is part of a model. The model can be very simple: for example, a graphical triangular model. The researcher should always know the model and think about it before setting out to collect the observations. It may occur that the existence of the model will help the researcher to determine their way of working, by guiding him or her to an adequate data collection procedure.

The practical use of statistical methods, physical and mathematical models and the graphical representation of their results would be extremely difficult and strenuous without the excellent modern computer programs we have at our disposal. It is tempting, therefore, to subordinate the research and its applications more and more to the methods and techniques of available computer science. However, doesn’t this book risk simply becoming a catalog of recipes? On the contrary, we think that it provides the necessary understanding of what programs can do in a few minutes. The explanations in this book eliminate the situation where the commercial programs are nothing but “black boxes” in the eyes of the user, implying the need to trust them blindly. This book considers itself to be a guide for making a choice from amongst the many methods suggested by the programs. Most of the time these methods are explained with the aid of tables and diagrams and illustrated with small maps of Luxembourg for which we never could imagine such a variety of possible representations.

Although such a guide is obviously helpful for a modern cartographer confronted with the available powerful and costly geo-informatic software, this is not the authors’ primary interest. It is concerned not so much with the immediate usefulness of recipes as with the logic of intellectual constructions which lead – often after many obstacles – to a trustworthy method. It is wonderful if the propositions of this book help to perfect the applications. However, it is also good if they only pose new questions, to which there is no solution yet. The important thing is to safeguard the freedom of learning, imagining and making mistakes! Paid researchers and employees should “make profit” and make deadlines. They are expected to produce publications at a specified date, without months to ponder the difficulties. Besides, even independent researchers would not survive if they
contented themselves with thinking at their leisure, hoping to become “discoverers”. Where is then the liberty required for thinking, without time constraints, if not in waiting for scholarship grants and various thematic programs? Perhaps it can be justified as necessary for perfecting the reliable methods which will produce a quick answer when a paid contract turns up, and with it the benefits – the carriers of the post-contract freedom which will be used to find the next know-how. Research has organized itself around a kind of “advance takings” basis, which is so familiar to our authors. It is the practices presented in this work that for example in 2005 enabled them to respond to the request of the Délégation à l’Aménagement du Territoire et de l’Action Régionale (DATAR) entitled “Exchange between public and private partners and interactive cartography of urban services” [CAU 05]. Their study dealt essentially with daily mobility in the cities of Belfort and Nancy. Among others, it brought about a real animated atlas published on a CD, showing the pulsation of openings and closings of urban activities hour-by-hour. This should help to improve public transportation and security. A large part of their work was devoted to structuring and querying the database. The animation and the interactivity made use of two groups of techniques developed in modern cartography: on the one hand, a series of dynamic images created independently from each other, and on the other hand, a transformation of the same image via motion (sprite), change of shape (twining) or change of color (color cycling). This book benefited from this recent experience.

But doesn’t the diffusion of original know-how, not protected by patents or copyrights, create the risk of the researchers’ work begin stolen, which in turn will lead to this diffusion stopping? There exists a conflict between education, popularization and research. The spreading use of the Internet is now leading us to rethink the nature and the legislation of the intellectual production. There can also be competition among researchers to know who will publish and hence divulge such and such new results for the first time. In a time when some governments are busy developing innovations, it is hard to see how they can protect them. Does it mean that our cartographers only present here unoriginal methods which belong to the public domain and do not violate their copyright?

Even if this was the case, it would still be completely unprecedented to have such methods assembled in a rational and accessible fashion. Besides, the animation (as well as the modeling) led the authors to a completely new approach to legend design.

And let cartographers rest assured: even after a careful reading of this book they will still have a lot left to do.

Nowadays, world geography is much more about a game of invisible flows than about descriptions of delimited territories. Financial flows in particular not only
cross borders, but use them. Some international companies have become more powerful than many states and instead of being impeded by the countries’ borders they profit from the differences in legislation. We therefore need to imagine a cartography of a moving flow network superimposed onto the framework of fixed borders. Of course it is difficult to represent changing flows. Such a representation constitutes the current research domain of several laboratories. In France, the CartActive group of GDR Sigma [MUS 06] is attacking the problem of dynamical cartography (moving maps) and interactive cartography (maps which react to the requests of the user). Our authors have tried their hand at these problems.

Moreover, major cities are becoming colossal: in the year 2000 there were 41 urban agglomerations with more than five million people. Although the cities concentrate activities more and more, the latter are impossible to represent as there are too many people at the same site. Should we therefore abandon any hope of representing the most dynamic urban centers because of graphical difficulties? Conversely, between these cities there are large back-water territories whose inhabitants emigrate to avoid the misery. What are we going to do about these problematic “holes” or, to use the expression of a contemporary geographer, these “murky fringes”?

Merging initiatives are appearing to deal with the international networks and the “holes.” For example, the European Union possesses a large administration which scrutinizes the management of these territories. With 27 Member States, the territories vary a lot and creating community descriptions which would allow international comparisons becomes a very delicate matter. How can we design maps which would enable us to compare the opportunities in Malta to those in Finland, in order to estimate what subsidies are needed for the goats of the former and the reindeer of the latter?

Moreover, how can we construct maps which demonstrate processes of both physical and socio-economic geography? Consider, for example, the process of migration of the Polish plumbers to Ireland, with the partially negative implications for the country of departure. Here we find the concept of information (where are the better salaries?), of structure (the transportation route) which the energy flow travels through (the migration), followed by the feedback (the reduction in the workforce which creates an adjustment in the original salaries). This takes us to thinking about and favoring the systems cartography linked to modeling. And here, too, our authors discover new directions.

Of course, the European Commission supports cartography via Eurostat, the European Space Agency, the Agriculture and Forests community and the IST program of risk reduction. Moreover, the launching of satellites to observe the Earth requires us to work on a global level and adopt the ellipsoidal model of the Earth,
both in geometric and physical applications. Thus, the Global Positioning System (GPS) of Navstar has adopted the ellipsoid of the World Geodetic System 1984 (WGGS84). Nevertheless, every, or almost every, European country uses a different ellipsoid and a different projection system which requires transformations in order to use them as a reference; see [DON 97]. The International Cartographic Association (ICA; see [CFC]) is in the process of standardizing this “geo-information”. This is going to be a long process. The present volume could bring if not a contribution then at least some thought to these regulation efforts to achieve “spatial data standards”.

Although locating observations on a scale less than 1/50,000 requires the mastery of coordinate transformations on ellipsoids and projections, the observations performed on larger scales can do without it. For them it suffices to make “adjustments” after the geometric corrections. This fact makes it possible to use Geographical Information Systems (GIS) in regional or local applications. The authors of our work do not miss the opportunity to use the data processing resources of GIS, as well as their visualization possibilities. These tools have been around for about 20 years. A very pedagogical Idrisi [BOS 94] of the “raster” (or matrix) type dates back to 1987. Its close contemporary ArcInfo (ESR 89) is a vector-type tool. GIS were quickly adopted by the public and private administrations. They are used for managing urban agglomerations and regions, for studying trading zones or for geo-marketing in private companies. In addition, the GIS of the 1980s enabled the resolution of the questions raised by the advent of the theoretical and quantitative geography in the late 1950s [HAG 91]. However, the good use of the GIS depends primarily on formulating the guiding idea: what are we trying to count, measure, add, extract, select, combine or simulate in order to give an answer to a question that has been posed? Choosing the third-order trend surface is not enough to demonstrate the attraction zone of a museum of modern art, a football stadium or the direction of spread of the Chikungunya virus. The GIS cartography is far from being “automatic”. A “spatial” way of thinking is needed, which is often multidisciplinary and draws on theoretical geography. This is why the authors did not hesitate to include numerous digressions which allowed them to follow the evolution of the discipline since 1960, when the first works of Waldo Tobler and William Bunge appeared. Of course, in 2003 a work was published in French [DAU 03] which traced the development of theoretical thought in geography, so that this book might seem to be redundant repetition. It is not, however, because this book treats cartographic methods and not the rules interrelated by some internal principles.

This book devotes a lot of attention to numerous transformations: transformations of data, of the reference frame, of the scale, of hypotheses, of colors, etc. A map nowadays is no more than a “snapshot” in the unrolling “movie” of possibilities. Transformational cartography enabled geography to pass from a descriptive stage, which was limited and static, to combinations of classifications,
spatial selections, observable and theoretical distributions, experiments and predictions. We hope that this book will help the readers to realize this, and also to show them the way to new applications. In 1985 Peter Gould [GOU 85] spoke of “the explosion in cartography” which we see today. He did not know what to call the new practices to distinguish them from the classical “cottage-industry” cartography: geomatics (as in Quebec)? Computer-assisted spatial analysis? Cartography on demand? Meta-cartography or rather computer-assisted theoretical cartography? We owe these last terms to William Bunge in 1962. As Paul Claval [CLA 64] reminds us, citing the prophetic words of Bunge which are now more than 40 years old, “…geography will no longer be divided into human and … physical, but into geography of points, lines and areas,” and they all “will be adorned by an abstract … general science, the theoretical geography.” It is this geospatial approach supported by cartography that distinguishes geography from sociology and economics, and gives it its unique character. Our authors go along this road. We hope that they will have provided future cartographers not only with a rich bibliography on the works of the past, but also with good tools to follow them and to outdo them.

Sylvie RIMBERT
Strasbourg, 2007

Bibliography


[CFC] Comité Français de Cartographie, 107 rue La Boétie. 75008 Paris. CFC is the counterpart of ICA in France, publishing “Le Monde des cartes”.


Maps\footnote{At this stage we will state that a map is “a simplified or conventional planar geometric representation of the whole or a part of the Earth’s surface with a suitable degree of similarity to the original” \cite{JOL76}. This term will be explored further in Chapter 2.}, in one form or another, were established and drawn very early on in history, in all epochs and all civilizations, as testified by the abundance of books and articles on this subject \cite{JAC92, KIS80}. These documents showed property boundaries, helped military operations, as well as showing the way for travelers. Maps multiplied and became abundant in the scientific domain, in the overview of the general public, as well as in planning organizations. They have become an object of frequent use in various activities: mountain hikes, road trips, as well as finding a hotel or a restaurant. The arrival of the tools for free access to digital maps, of which Google Earth is certainly the most prominent example, further reinforces the importance of maps, either topographic or thematic, in the modern world. We live in a society of maps. Nevertheless, are the correct uses of a map, its creation and the possibilities it offers well known?

These questions are pertinent when we look at the maps published on paper (in magazines, books or atlases) or on screen (on the web). There we find carefully designed, highly complex maps, though illegible, as well as simple schematic documents, crudely and imprecisely drawn, possibly attractive but misleading. Everyone believes that he or she is capable of creating a map, as if using a computer is sufficient for obtaining an immediate response to a particular request. Maps are required “right away”, as if “push button” maps existed and a map’s validity was automatic. In reality, even before making a map, we need to know what the actual request is, whether the map is truly needed or whether a table would be more appropriate. Given the current proliferation of maps, their abundance and the dangers inherent in the variety of technological possibilities, it is important to
carefully determine the necessary mapmaking route, in order to put cartography\(^2\) into a more strict, rigorous setting and to produce a reliable document. This leads us to considering cartography and maps in a new light and to proposing a novel approach, after having identified new objectives.

The approach presented in this book utilizes cartographic reasoning, which puts mapmaking within a larger experimental scientific approach. A map is no longer a document produced in an isolated fashion, simply for illustration. It is a constructed image incorporated into a larger study, which at a given point of its development warrants the production of a map. It is therefore necessary to explain the context which justifies the map, to know its intended recipient in order to determine the theoretical and contextual elements on which the production of the map will hinge and based on which further choices will be made. The cartographic reasoning is meant to instruct us how to “dissect” a map request, in order to ascertain which questions to ask and what range of answers to offer. In fact, there is no unique answer for each request: “the Map does not exist. Among others, there are solutions that produce maps more appropriate to a given purpose.

This reasoning provides a loose guide, which can incorporate changes, both conceptual and technical. Making a map by “clicking” a computer mouse may produce an image, whose quality or reliability cannot be certain: inaccurate data and improper processing do not produce correct maps. Wrong signs, inadequate representation modes will not yield accurate, meaningful information. Making a map based on cartographic reasoning allows us, however, to recreate an image whose elements can all be justified and explained and whose quality is assured. It produces a document which the recipients can use for deliberations, for asking and answering questions without worrying about the validity of the initial information. In order to achieve this, the map’s author should be familiar with the readers’ interests, objectives and capabilities.

From this point of view, a map is not a simple illustration accompanying a text because for most it is more pleasant to look at than a table. Depending on the context, it becomes a tool for deliberation or research, a “revealer” of hidden structures, or a supporting document, allowing partners to have concrete discussions. Nevertheless, we should not forget that regardless of its context, a map is always the result of at least a minimum amount of research: even for an illustration, we need to have some knowledge concerning the thematic phenomena represented and the locations in question. This presupposes a certain amount of

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2 Here cartography is defined as “the set of scientific, artistic and technological studies and operations starting from the results of direct observations or the use of documentation with the aim of creating maps, plans and other modes of expression, as well as their usage” [JOL 76]. This term will also be clarified in Chapter 2.
preliminary study. It is based on this knowledge that a map can be established and can fulfill its multiple functions. Indeed, while preserving its initial function of locating observable spatial phenomena, the map also acquired the function of locating the characteristics which are invisible and which underlie these spatial phenomena both in structure and process. The map becomes, therefore, a tool for discovery, and cartography becomes a discipline of localizing the invisible.

This work on thematic cartography thus provides a guide to making a map, such that the map fits the requirements which originated its production, be it in the framework of a hypothesis in a study or the work of a consultant office. Although work conditions may differ, the basic principles are the same, and the guiding thread is identical, since a map is always produced via a succession of very particular stages.

An important point, which we will emphasize, is the dynamic component of cartography, which manifests itself throughout production stages that include all the transformations. We cannot proceed from the Earth to the map without transforming the elements present on the Earth and those depicted on the map. We will show that a map is the result of a series of transformations, each of which plays a specific role and requires a particular field of expertise. No longer can a map be designed by the two classical co-authors – the cartographer and the thematician. It needs the expertise of geomaticians, computer scientists, mathematicians and semioticians, which has its positives and negatives. On the one hand, because of the diversity of the domains which come into cartography, and the proliferation of experts or amateurs who consider themselves cartographers, a certain confusion is created, which considerably damages the final product, the map. On the other hand, the cartographic discipline is constantly expanding thanks to the contributions of the related disciplines and is gradually turning into what is currently called “geovisualization”.

Irrespective of the name given to the discipline, a map must be useful and serve a purpose. It is no secret that a map is not always legible and reliable: being overloaded or badly drawn (lines too thick or too thin, for instance), it is not useful. A map should be of good quality and should present accurate information. Like any science, cartography must follow deontology rules. This is especially sensible today, when maps are circulated on the Web, mutually enriching each other, subject to their original quality.

In the three volumes of this book, the various transformations leading to the production of the map will be discussed sequentially.

Volume 1 contains the stages and the expertise necessary for the production of any thematic map. The content is standard, but as mentioned above, the approach is