Practical Handbook of Thematic Cartography

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Principles, Methods, and Applications

Nicolas Lambert and Christine Zanin

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Contents

PART 2 Cartographical Language

PART 3 Beyond the Visual Variables

Foreword

In the geospatial domains, we can witness that more spatial data than ever is produced currently. We need to make more and more efforts to deal with all those data in an efficient sense, mining the relevant information and link and select the appropriate information for a particular scenario.

However, how can we unleash the big potential of spatial data in truly interdisciplinary approaches better? How can we make sure that spatial data is applicable for governments, for decision-makers, for planners, and for citizens in an easy-to-use and efficient manner, so that the human user benefits?

In this respect, maps and cartography play a key role. Maps are most efficient in enabling human users to understand complex situations. Maps can be understood as tools to order information by their spatial context. Maps can be seen as the perfect interface between a human user and all those data, and thus they enable human users to answer location-related questions, to support spatial behavior, to enable spatial problem solving, or simply to be able to become aware of space.

Today maps can be created and used by any individual stocked with just modest computing skills from virtually any location on Earth and for almost any purpose. In this new mapmaking paradigm, users are often present at the location of interest and produce maps that address needs that arise instantaneously. Cartographic data may be digitally and wirelessly delivered in finalized form to the device in the hands of the user or he may derive the requested visualization from downloaded data in situ. Rapid advances in technologies have enabled this revolution in mapmaking by the millions. One such prominent advance includes the possibility to derive maps very quickly immediately after the data has been acquired by accessing and disseminating maps through the Internet. Real-time data handling and visualization are other significant developments as well as location-based services, mobile cartography, and augmented reality.

While the above advances have enabled significant progress on the design and implementation of new ways of map production over the past decade, many cartographic principles remain unchanged, the most important one being that maps are an abstraction of reality. Visualization of selected information means that some features present in reality are depicted more prominently than others, while many features might not even be depicted at all. Abstracting reality makes a map powerful, as it helps humans to understand and interpret very complex situations very efficiently.

However, as geodata and mapmaking software instruments become available to many, the need for understanding background, fundamentals, and methods of successful cartographic modeling processes raises significantly. It is rather interesting to witness how many maps are produced nowadays lacking fundamental rules of cartographic practice, thus demonstrating a lack of knowledge.

It is this context which makes every contemporary handbook or manual on cartography highly relevant. What is the fundamental knowledge I should have when dealing with maps, when trying to depict spatial information by graphical means and convey a story, a message for the benefit of human map users? Can there be a manual that describes all the theoretical and methodological underpinnings of cartography but gives at the same time easy-to-understand examples as well as discussing on a holistic level the consequences, limitations and constraints of maps and cartographic processes?

Of course, there are several textbooks, guidebooks, and introduction materials to cartography available, some of them quite old and some of them more technologically focused. The excellent *Manuel de cartographie* published in 2016 by Nicolas Lambert and Christine Zanin in French offered everything needed to gain a mutual understanding of modern cartography. It is a real benefit to the non-French-speaking world that this book is now available in English as well.

It demonstrates a holistic understanding of cartography in the tradition of the famous “Sémiologie Graphique” from Jacques Bertin. This book is divided into a logical “stack”, starting with fundamentals on the “input” for mapmaking (basemaps and statistical data), on the methods and concepts of transforming data into graphics and finally, in a more critical approach on looking beyond the visual variables, thus giving insight on how to go even further in cartographic design. With this, interested readers get something like a profound compass in their hand, which can guide them through the amazing world of cartography and help to ensure, that not only spatial data and geotechnologies become available on the fingertips of many but also the theoretical and methodological underpinnings of cartography. As a result, I expect many better maps being produced in future!

As former president of the International Cartographic Association, I claimed always that

1. Cartography is relevant
2. Cartography is modern
3. Cartography is attractive

and that it is therefore “OK, to be a cartographer!”.

This book demonstrates why cartography is relevant, modern, and attractive. *Félicitations*, Christine et Nicolas!

Georg Gartner, Vienna

Authors

Nicolas Lambert is a research engineer in geographic information sciences at the CNRS (French National Centre for Scientific Research). Passionate about cartography and dataviz, he has made this activity his core work. He designs geographical maps to decrypt the world but also "protests" maps to try to transform it. As a political and associative activist, he has been involved for nearly 10 years in the cause of migrants within the Migreurop network. He regularly shares his maps and works on the blog neocarto.hypotheses.org. He is known on twitter as "cartographe encarté" (@nico_lambert).

Christine Zanin is a professor and researcher in geography and cartography at the University of Paris Diderot and the UMR Géographie-Cités. Her passion for maps and the graphic world leads her to think of a pedagogy committed to cartographic design that respects visual rules but is in search of the innovation made possible by new digital tools. How to think about the spatial organization of territories through the cartographic prism is the meaning of her research.

Nicolas Lambert and Christine Zanin have been working together for more than 10 years to advance cartographic expression in all aspects of their professional or personal commitments. They were jointly awarded the 2009 Paris Diderot University Innovation Prize and published in 2016 the *Manuel de Cartographie* in French to understand and apply the different ingredients for effective mapping. In 2019, they also published *Mad Maps*, an atlas of 60 unpublished maps for the general public to help disseminate mapping.

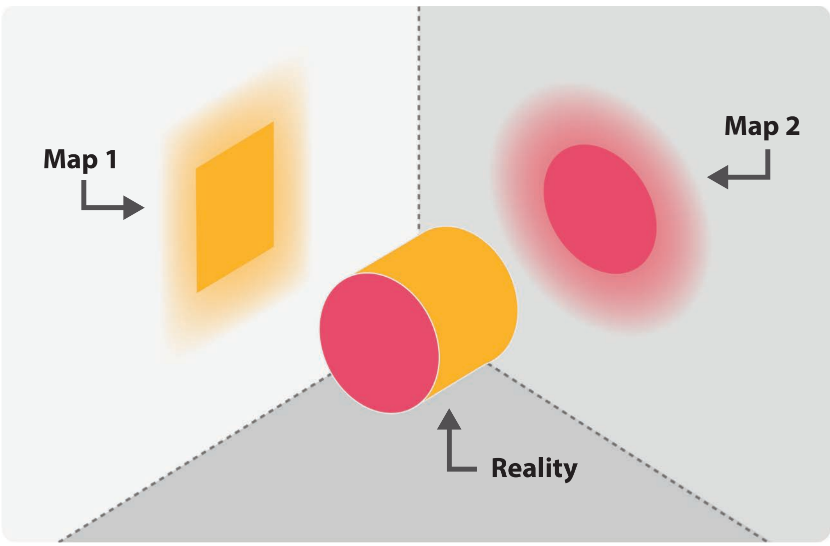
A map of the world that does not include Utopia is not worth even glancing at, for it leaves out the one country at which Humanity is always landing. And when Humanity lands there, it looks out, and, seeing a better country, sets sail. Progress is the realisation of Utopias.

Oscar Wilde, *The Soul of Man under Socialism*

General Introduction

"La trahison des images" (The Treachery of Images), one of René Magritte's most famous works, painted in 1929, depicts a realistic-looking pipe in profile, resting on a caption painted in the picture "Ceci n'est pas une pipe" (This is not a pipe). With this picture, Magritte wanted to demonstrate that, even if it is the most faithful representation of a pipe, its representation is never really a pipe: it cannot be smoked; it cannot be touched or handled. According to Magritte, a picture is always a representation of an object, but not the object itself. This painting is therefore not reality, but a representation of it, according to hypotheses, intentions, and technical know-how.

Figure GI.01 Any map is a point of view on reality.



Long considered as an impartial, neutral scientific representation of geographical space, "a map is not a territory" (Korzybski, 1931). Resulting from choices and simplification, a map is "a" representation of reality and not reality itself. It is "the production of something concrete and unfamiliar that is converted into an abstract representation" (Lacoste, 1976). Indeed, a map is the "result of a set of technical gestures materializing an idea" (Jacob, 1992). All maps are therefore subjective. They offer a particular proposition, and they do not reflect the world objectively (Brotton, 2014). The possible designs are infinite.

FOCUS: The Cartographer's Eye

Behind a map, there is always a cartographer. If you have 100 cartographers on the top of Empire State Building and ask them to map Manhattan, you will get 100 different map representations. The discrepancy between reality and the image representing it is inevitable. It is all the more true when the phenomena to be mapped are not visible to the naked eye, as it is often the case with human geography. A cartographer is therefore someone who, through his eye, shows to our eye what cannot be seen, a magical eye capable of making the invisible, visible.

I.1 WHAT IS A MAP?

The term "map" can be declined in several entities. There is a multitude of geographical maps: weather maps, geology maps, vegetation maps, climate maps, tourist attractions maps, road maps, location maps, animated maps, interactive maps, etc.

It's possible to classify all maps in two main categories:

Topographic maps are maps that mainly show results of direct observation: relief, water courses, human constructions, etc. These maps represent concrete elements that are durably established on a portion of terrestrial space at a given time.

Thematic maps are maps on which localizable qualitative or quantitative phenomena of all kinds are represented. Information is represented according to the rules of graphic semiology. These maps are designed, laid out, and "staged" to produce an intelligible image of the geographical phenomenon at hand.

Definitions

A **map** is a simplified and codified image of geographical space, representing its characteristics and/or its organization. It is the result of a creative action and of the choices made by its author.

Cartography is an artistic, scientific, and technical discipline that aims to conceive and draw up maps.

A **cartographer** is someone who masters the methods, techniques, and concepts of converting geographical information into images.

I.2 WHY DO WE HAVE MAPS?

Maps are the starting point and culmination of a geographer's work. They are his specific tools. To put it simply, maps are used to understand space, physical, and human organizations, etc. They enable information to be spatially represented, visualized, and analyzed. Maps allow discovering territories, carrying out and testing hypotheses, and learning about spatial organization. But above all, they are used for communication. Conceived as a way to communicate, they let to transmission of information or ideas, and help to understand geographical analysis.

Geography textbooks are full of maps giving students explanations about different phenomena. The more pedagogical is a map, the more effective it is. All in all, a map serves to tell us about a territory. For it, and to do this, we need to choose words, colors, and curves for the layout, and to adapt to the population targeted. Each map should be designed specifically for a particular group of people and should expound a subject that is thoroughly thought-through.

FOCUS: Where Does the Word Cartography Come From?

The word "cartography" stems from the Greek word *khartes* and the Latin word *carta*. It comes from the designation of the medium that was used: parchment. More recently in Europe, it was the German geographer, Karl Ritter of the Berlin Geographical Society, who used the word *Kartograph* for the first time, in 1828. A year later, the French Cartographic Society followed suit by using the word *cartographie*. In 1859, the British also took over the word "cartography". In addition, the word "map" comes from *mappa*, which is a piece of fabric. It should also be noted that the word "chart", phonetically close to the French word *carte*, refers more to a statistical nonspatial representation (pie chart, diagram).

I.3 WHAT IS THE PURPOSE OF THIS HANDBOOK?

This handbook is about thematic cartography. It has been designed as a practical and fully illustrated tool for students to use in geography or infographics. It contains more than 130 figures. It can be read from beginning to end like an essay or read by dipping into it for the information needed.

FOCUS: Cartography, Mapping, or Geoviz?

These three words seem to mean the same thing and seem to be used to describe the process of designing maps nowadays. However, their meanings are not exactly the same. The term "mapping" refers more to the world of GIS and to the display and overlaying of layers of geographic information. The word "cartography" is most often used to designate a meaningful representation (map with message) by combining geographical and statistical data (e.g., thematic or statistical cartography). Finally, the term "Geoviz" (for Geovisualization) always requires a digital and interactive support. Three words, three different worlds.

This handbook is composed of three parts. Part 1 gives details on how to use, construct, and manage the raw material at the cartographer's disposal, i.e., basemaps (Chapter 1) and statistical information (Chapter 2).

Part 2 looks more specifically at the methods and concepts of transforming data into graphic form. The representation of different types of data is introduced: nominal qualitative data (Chapter 3), ordinate data (Chapter 4), and absolute quantitative data (Chapter 5). In addition, Chapter 6 gives information on the use of cartography in particular contexts: temporal data, comparisons, typologies, multivariate analyses, etc.

And finally, in a more critical approach, Part 3, entitled "Beyond visual variables", gives details on how to go even further in cartographic design. Innovative cartography methods are presented (Chapter 7). The choice of the layout and general "staging" (in a theatrical sense) of the map are described in detail (Chapter 8). To conclude, Chapter 9 demonstrates the subjectivity of cartographic images enabling the description of geographical space.

With this handbook, we hope to rehabilitate the term "cartography". Often taken, wrongly, as old-fashioned, in favor of the more contemporary term "geomatics", cartography has nonetheless some advantages. It is a rich and abundant discipline. When we design maps, we become at the same time explorers and pedagogues. Spatial structures are explored, we strive to understand how geographical space works, we analyze it, and we dissect it. Once the analysis has been carried out, results have to be shared. To do this, cartographers design images to tell us about territories. They formalize and depict space and build a world by materializing the imperceptible.

Any map is an invitation ... to see, dream, think, and act. So let us dream, imagine, create, and make maps. And proclaim its legitimacy!

MAP GAMES

At the end of every section, there are exercises to put into practice the notions that have been presented. With what you learn in the different stages described in this handbook, the objective is step by step to enable you to design a map in accordance with your own particular choices. Your homework will be to produce an interesting and communicative image. The imposed theme, in this game, is the distribution of the US population, but it can naturally be applied to any spatial theme.

The game consists of three parts.

Part 1: You will focus on acquiring a coherent set of data, structured and exploitable in a mapmaking approach (basemap, statistical data). In this part, it is important, if required, to process and convert the acquired data (generalization of basemaps, data discretization, etc.)

Part 2: You will produce the chosen map using graphic ways suited to the nature of the data acquired during Part 1.

Part 3: This concerns the final development phase of the map: you will choose the layout and the "staging" of the cartographic image.

Be aware that the proposed theme (or any other theme) can be addressed in a number of different approaches you are free to choose from total population, density, young people, the elderly, men, women, demographic projections, life expectancy, birth rate, death rate, etc. You also have a free choice of techniques and software you are used to.

A brief history of cartography…

"Writing history makes a mess of geography!"
Daniel Pennac, *La fée carabine*, 1987

…just to have some important cartographic steps in mind!

THE EARLY MAPS

Geography precedes history. To appropriate their environment, humans have long sought to represent the space around them. Certain maps actually predate the invention of writing.

2200 BCE	**The Nuzi tablet** On one of the Nuzi tables found in Mesopotamia near Kirkuk is a map engraved in clay. It is the oldest map ever found.
2000 BCE	**The Belinda map** A map found on the walls of Belinda cave in northern Italy.
600 BCE	**The Babylonian map of the world** A map engraved on a clay tablet found near the town of Sippar, southern Iraq. It is the first attempt to map the world.

GREEK SCIENTIFIC CARTOGRAPHY

The Greeks were pioneers of scientific cartography, representing the shape of the Earth and inventing systems of projection.

650 BCE	**The Earth is a disc** Thales of Miletus saw the earth as a flat disc floating on water.
550 BCE	**The Earth is a sphere** For Pythagoras, the Earth was necessarily the most perfect geometrical shape – a sphere.
500 BCE	**The first map of the Ecumene** Anaximander and Hecataeus drew up the first map of the known world, seen as a flat disc centered on the Mediterranean. Three continents can be seen: Europe, Asia, and Africa (Libya).
200 BCE	**The first estimation of the circumference of the Earth** Eratosthenes, curator of the Great Library of Alexandria, performed the first measurement of a meridian arc and made the first estimate of the circumference of the Earth.

120 CE	**Ptolemy's geography** Ptolemy is considered to be the last great academics of Antiquity. In his *Geography*, he compiled all the geographical knowledge of the time. This work includes 27 maps: 12 maps of Asia, 10 of Europe, 4 of Africa, and 1 of the world.

THE UTILITARIAN MAPS OF THE ROMANS

Drawing away from the Greek scientific approach, the Roman maps were restricted to practical and utilitarian aspects – military maps, property maps, and routes.

300 CE	**Peutinger's Tabula** This itinerarium comprises eleven rolled parchments accounting for 200,000 km of road, surviving in a 13th-century copy. It is the ancestor of our road maps.

THE MIDDLE AGES

In the Middle Ages, European cartography went through a period of virtual vacuum. The medieval mapmaker seems to have been dominated by the church, reflecting in his work the ecclesiastical dogmas and interpretations of scripture. Maps were more symbolic than geographical. The church adapted maps to a mystical and contemplative ideology.

From the 8th century	**T-O maps** The cartographic representations of the Earth to the form of a T inside an O. Oriented east, these maps return to the three continents (Europe, Asia, and Libya) discovered by the Greeks. They are separated by two perpendicular rivers: the Nile and the Don (Tanais).
1240	**Ebstorf's world map** The Ebstorf mappa mundi divides the world into three zones corresponding to the sharing out of the world by Noah's sons after the flood. In the center of the map, we find Jerusalem. Christ dominates the top of the map. On this particular map, on account of the complexity of the information included; the T-O structure is less prominent, although still present.

THE ARAB AND ASIAN WORLDS

While scientific mapping was set aside in the West, it re-emerged from the 8th century in the Arab world. By re-appropriating Greek geography, the Arab academics renewed the somewhat forgotten discipline. Arab maps served as a link between West and East.

950	**The Istakhri map** The Istakhri map, centered on the Moslem world, is oriented southwards towards Mecca. Here, Europe is reduced to a triangle to the bottom right.
1154	**The Al-Idrisi world map** Al-Idrisi was the geographer and physician of king Roger II of Sicily, and was also a great traveler. He visited China, Tibet, and Europe as far as Scandinavia. Although the maps are circular, for Al-Idrisi the Earth was indeed spherical. His maps served as a basis for the first marine maps (portolan charts).
1402	**The Kangnido map** Korean world map where European and African continents are designed. China and Korea are oversized. Unlike European or Arabian maps, the Kangnido map presents a square shape.

THE REVIVAL OF CARTOGRAPHY (THE GREAT DISCOVERIES)

From the 13th century, mapmaking saw an unprecedented rise, at a time when the conquest of new territories primarily required a mastery of sea navigation. The maps were now oriented towards the magnetic north indicated by the compass. Progress in technologies such as navigation, ship design and construction, instruments for observation and astronomy, and general use of the compass tended continuously to improve existing map information, as well as to encourage further exploration and discovery.

1290	**The Carta Pisana** The Carta Pisana is the earliest marine map known. It is the first of a series of maps produced from the 13th to the 18th century – the portolan charts. On these maps, only coastal cities are marked. Portolan charts are based on the compass rose or wind rose, and on rhomb lines, and they have no reference system of coordinates.
1492	**The first terrestrial globe** The first known terrestrial globe was made by Martin Behaim in Nürnberg.

1507	**The first map of America** The Waldseemüller planisphere is the first map to show the word "America".
1524	The first edition of the Petrus Apianus textbooks of geography illustrated with maps and figures reflecting the general eagerness of the times for learning, especially geography.
1569	**Mercator** The Mercator map was above all a marine map. It was intended to facilitate the task of navigators in keeping on course.
1570	**Ortelius** First modern atlas.

TOWARDS A GREATER ACCURACY

During the 18th century, cartography was characterized by scientific trends and more accurate details. Factual content was privileged with all the increasing information available, often with explanatory notes, and attempts to show the respective reliabilities of some portions. The new cartography was also based on better instruments, the telescope playing an important part in raising the quality of astronomical observations.

Topographic activity is now reinforced to some extent by increasing civil needs for basic data. Many countries of Europe began to undertake the systematic topographic mapping of their territories. Such surveys required facilities and capabilities far beyond the means of private cartographers who had theretofore provided for most map needs. Originally exclusively military, national survey organizations gradually became civilian in character. The Ordnance Survey of Britain, the Institut Géographique National of France, and the Landes topographie of Switzerland are examples.

1761	**The measurement of longitude.** The clockmaker John Harrison devised the first chronometer to cope with the ocean swell, thus enabling accurate measurements of longitude at sea.
1682	**A Map of France corrected on orders from the king**. Using recent technical and scientific progress, Picard and La Hire drew up a more precise map of the contours of France. On this map, the kingdom appears smaller than before, to the great despair of Louis XIV.
1760–1815	**The Cassini Map**. This is the earliest triangulated map of the kingdom of France. It was drawn up on the initiative of Louis XV and occupied four generations of a family of cartographers, the Cassini, who devoted their lives to the establishment of this map, which was of unprecedented accuracy.

1799	**The meter**. Between 1792 and 1798, Delambre and Méchain measured the distance between Dunkirk and Barcelona along the Paris meridian. This measure was to serve as a universal reference to finally define the standard meter.
1891	The International Geographical Congress in 1891 proposed that the participating countries collaborate in the production of a 1:1,000,000-scale **map of the world**. By the mid-1980s, the project was nearing completion.

PIONEERS OF DATA VISUALIZATION

In addition of the cartographic history, we find some non-geographic representation.

1370	**Nicolas Oresme** represents in graphical form the relationship between two variables and prefigures the first bar charts.
1786	**William Playfair** invents three types of graphic design: bar chart, curve, and pie charts.
1858	**Florence Nightingale** shows with a pie chart the cause of the death soldiers during the Crimean War.

THE BIRTH OF MODERN THEMATIC MAPPING

The start of the 19th century saw the emergence of autonomous thematic maps, illustrating statistical information of demographic, sociological, or economic nature. Mapmaking was becoming a fully fledged discipline. Thematic mapping is the result of the convergence of classical mapping and data visualization.

1826	**The first statistical map** Charles Dupin produced the first thematic map in history – a figurative map of popular education.
1828	**The appearance of the term "cartography"** The German geographer Karl Ritter used the word "Kartograph" for the first time.
1869	**Charles Joseph Minard** represents the colossal losses of the French army in the Russian campaign at the beginning of the 19th century. This famous map is nowadays considered as a "gold standard".

CONTEMPORARY CARTOGRAPHY

Today maps are no longer drawn by hand; they are designed on a computer. Maps have diversified – they can be interactive, animated, participative, three-dimensional, etc. As they are easier to produce, they have become part of our everyday lives.

1940	**The first computer** The mathematician Alan Turing established the theoretical basis for what would become a computer.
1960	**The quantitative revolution in geography and the first Geographical Information System (GIS)** Drawing on the resources offered by mathematics and computing, geography sought to define itself as a fully fledged science. The year 1960 also saw the establishment in Canada of the first GIS.
1966	**The first photograph of the earth** This first image of the earth from space was taken from the moon orbit by the Luna Observer spacecraft.
1967	**The Graphic Semiology** Jacques Bertin published the founding treatise on contemporary cartographic language, *La Sémiologie Graphique*.
2004	**The launching of Google Maps** While maps were for a long time the prerogative of nation states, today it is an American multinational that offers accurate maps of the whole world.

Part 1

Geographical Information

After having told young children that the Earth is round, that it is a ball rolling through space like the sun or the moon, can I then show them an image in the shape of a rectangular sheet of paper with colored images? [...]Should I try to make these little ones understand that the sphere has been changed into a planisphere (flat world map) – in other words, if I correctly understand the two juxtaposed words, a flat sphere?

Elisée Reclus, *Learning Geography,* 1903

INTRODUCTION

Data mobilized in geography and cartography is referred to as geographical data. This data relates to space and/or to phenomena localized on the surface of the Earth. Any information with an address or any element enabling localization in space (e.g., the identification of a place or a landscape) can become a piece of geographical information. Several definitions are proposed. According to Michael Frank Goodchild (1997), geographic information is information about places on the Earth's surface, knowledge about where something is, and knowledge about what is at a given location. In summary, it is information that relates to one or more places in the terrestrial space (Beguin and Pumain, 2014). The geographic space is determined by reference to coordinates, either longitude and latitude for conventional mapping or some others forms for distorted maps.

Geographical information makes it possible to orient in space (where is a given phenomenon to be found?) and to compare localizations (why here rather than elsewhere, why here more than elsewhere?). In geography, this characteristic is essential, because a single, isolated piece of numerical data has no real meaning. It takes on meaning in comparison with other localities.

FOCUS: Data or Information?

The terms "data" and "information" refer to concepts that overlap and can appear as synonymous. Data can be stored (figures, written material, photographs, videos, etc.). Information is the result of the action of interpreting data. For instance, gross domestic product (GDP) data give us information on the wealth of a country. It is possible to store the data enabling information to be produced from a database, but not this information itself, which results from a process of construction and interpretation. It is nevertheless common to speak of geographical information when what is meant is geographical data. This handbook is no exception.

To give data a spatial dimension, there are two possible operations:

- ***Geo-referencing*** consists in positioning or marking by hand an object on a reference basemap. This operation can be conducted with the computer mouse, identifying the place to be referenced by a click, or by entering the geographic coordinates of the object if these are available directly, using the keyboard. Adjusting an image involves positioning exactly an object (such as an aerial photograph), so as to superimpose it on the basemap. Geo-referencing can also be performed directly in the field using a GPS device.
- ***Geocoding*** consists in attributing geographic coordinates (longitude, latitude) to an address. To do this, a database is required giving references for each section of road, along with tools to exploit the database. These geocoding systems, which were for a long time on offer on the market, are now available, free of charge. For the USA, the website https://www.census.gov makes it possible to geocode addresses across the national territory via an online application.

It is often said that there are two types of geographical information:

- ***Reference information*** concerns general data that can be used in numerous areas of activity: administrative boundaries, road networks, countries across the world, etc. A lot of this information is freely available online.
- ***Thematic information*** concerns particular themes. It can be produced by businesses, study bureaus, or specialists of one or other domain. This information is more specialized and generally come at a cost. Today, the open data movement is facilitating access.

FOCUS: Open Data

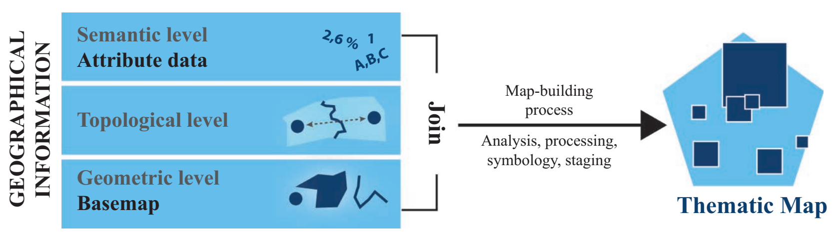
Open data is a movement that started up in the USA in the 1990s. It expanded in the 2000s with the development of Internet. It consists in issuing data (geographical or other) with an open license guaranteeing free access and use of the data. Today, many countries and cities around the world have switched to Open Data, which greatly facilitates the work of cartographers.

Whether the geographical information you are to use concerns reference information or thematic information, it can be divided into three types:

- **Geometric information**, formed by points, lines, and polygons, describes the shape, the contour, and the localization of objects within a system of geographical or Cartesian coordinates. This is the basemap (Chapter 1).
- **Semantic information**, made up of numerical values or text, relates to an object that is localized in space. It can be the name of a street, a plot number, or statistical information concerning the particular territorial unit (e.g., the number of inhabitants in Cherokee County (North Carolina). This type of data is often known as attribute data (Chapter 2).
- **Topological information** is information deduced from the geometrical information. It is defined by spatial relationships between objects: proximity, distance, contiguousness, inclusion, etc. It can generate specific cartographic representations such as discontinuities, multi-scalar typologies, or smoothing.

Any thematic map will be the result of a combination of a basemap (geometrical information) and one or several types of data (semantic information).

Figure P1.I1 From geographical information to the thematic map.



Geographical information is the cartographer's raw material. Making a map means converting geographical information into an image. Which basemap should be used, what cover, what level of generalization, which type of projection, which grid? What is the best statistical indicator to use, how should it be expressed, should you use raw or converted data? These initial choices are all part of the process of designing a map. The first part of this handbook will seek to describe in detail the two main components of geographical information, essential for the design of thematic maps: geometric information (the basemap) and semantic information (attribute data).

Chapter 1

Geometrical Data

Objectives

- Choosing and/or creating a basemap
- Knowing the principles of generalization
- Knowing the differences between a vector image and a raster image
- Understanding the issues raised by cartographic projections
- Understanding the impact of spatial subdivisions on cartographic representations.

Choosing a basemap, whether to be developed from scratch or merely downloaded from the Web, is an essential step in cartographic creation. The basemap is what will contain the information that is to be represented. It is the base that enables the spatialization of a phenomenon. It needs to be suited to the complexity of the map to be developed, and to the objectives of the cartographic project.

1.1 GEOGRAPHIC OBJECTS

A basemap is made up of a set of geographic objects that need to be chosen carefully, according to the level of detail required, the medium used for the representation (paper or digital), its purpose, and the type of public targeted. There are three types of geographic objects (three basic graphics): the point, the line, and the polygon. These geographic objects can be constructed in two modes: vector and raster (matrix). They are linked to one another via a spatial relationship (proximity, distance, contiguity), by their size and by their shape. These objects can be geo-referenced and stored in coherent manner in a geographic information system (GIS). They form layers that can be superimposed, crossed, and used to develop a basemap. They enable the reality of the world to be "drawn" or depicted on a flat surface (a sheet of paper or a screen).

In thematic mapping, vector basemaps are the more frequently used. Unlike the raster format, the vector format enables a single identifier to be associated with each object, which in turn enables these objects to be linked individually to statistic tables using the same codes. This operation, which is widely used in cartography, is known as the **join**. Once the map is completed, it can easily be revised using CAD (computer-aided design) software. It is thus possible to alter, re-size, or complete the image without pixelization or loss of graphic quality (see Chapter 8).

Definition

Join: a join consists in the linking of statistical information to an object that is already localized, by confronting two identical codes.

Figure 1.01 Layers to model reality.

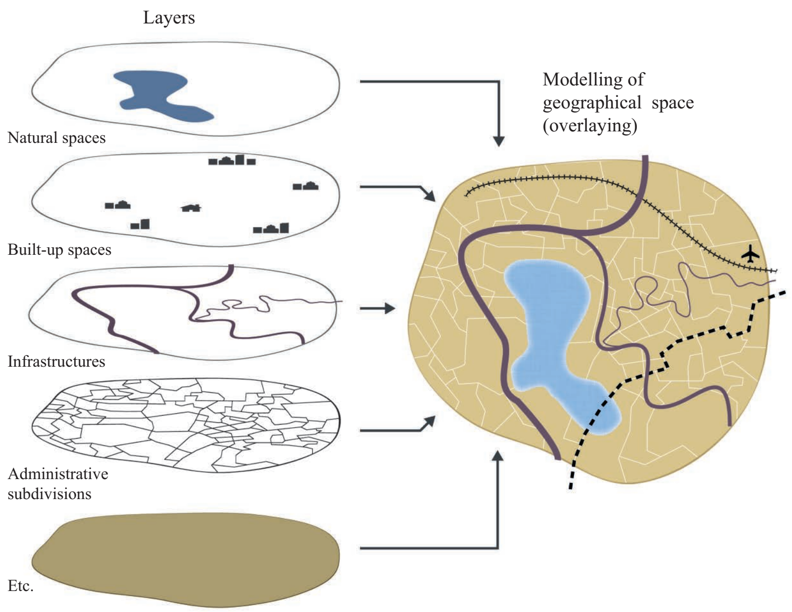
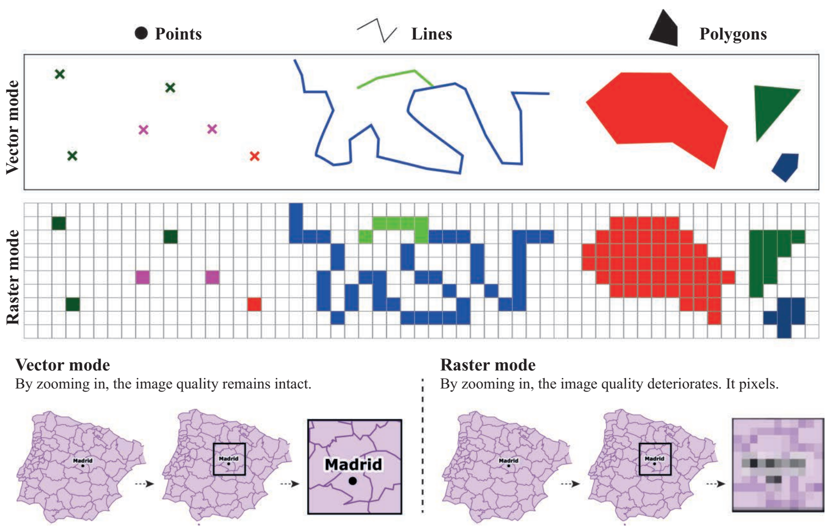


Figure 1.02 Vector and raster.



A basemap is determined by four elements: the way in which the space represented is laid out (the **projection**), the choice of the portion of terrestrial space considered (the **spatial extent** and the **orientation**), the way in which the basemap is drawn (the **generalization**), and the geographic objects represented on it (the **spatial subdivisions**). The choice of these elements is essential in map design. Although in practice the cartographer will not create a new basemap for each new map, he or she will nevertheless need to be realistic and critical with regard to the materials to be used: why this basemap rather than another? Can it be improved? What impact does it have on the message to be conveyed by the map?

Indeed, while the basemap is a mere "container", it is also the framework and the medium of the geographic information to be represented. Information is laid out on it, and at the same time, it is itself a part of the information. Drawing dividing lines and borders has an impact on the visual quality of the transcription of the message and hence on its efficacy. Choosing specific spatial subdivisions on which the information is to be described, and deciding whether it is suited not only to the data but also to its representation are the first issues to be considered by cartographers, whether novice or experienced. Below are a few elements to help in these decisions.

1.2 PROJECTIONS

Whatever the base medium used (a sheet of paper, a computer screen, or a tablet), the world has to be laid out flat, or "projected" in order to be seen in its entirety.

Although for Aristotle, the area covered by "dry land" and inhabited by man was sufficiently small to be assimilated to a plan (Claval, 2011), the mathematical process that consists in converting a three-dimensional space into something that is flat already preoccupied the Greek geographers of Antiquity. This operation involves several constraints: there is no ideal projection, and any projection produces distortions. Two basemaps that do not have the same projection cannot be correctly superimposed. The larger the space represented, the greater the distortions. This conversion operation enabling the shift from the spherical earth to the Cartesian plane (the basemap) is conducted in several stages.

FOCUS: How Long Have We Known That the Earth Is Not Flat?

Despite what is often said, humanity has known for a long time that the Earth is not flat. In *The Geography*, Ptolemy (90–168 CE) already gave a description of two projections that could be used for a map of the ecumene (areas that are known, inhabited, or exploited by man). Before him, Eratosthenes (276–194 BCE) calculated one of the first estimations of the terrestrial circumference, 39,375 km, which is very close to reality (40,075 km).

1.2.1 Finding a Localization on the Surface of the Earth

The Earth can be assimilated to a sphere, but it is not a perfect sphere. There are mountains and ocean trenches, so that the Earth is irregular in shape. To obtain a simplified representation of the terrestrial surface, we need a theoretical intermediate surface, which is known as the geoid and corresponds to a measure of the Earth's field of gravity. The **geoid**, which coincides with the average ocean surface, provides a precise representation of the Earth's surface without the relief. It is the surface area at altitude zero. But far from being a perfect sphere, the geoid is itself distorted. It is flattened at the poles, and different points on the surface of the geoid are not all at the same distance from its center.

Starting from the geoid, it is possible to define the most representative **ellipsoid**. This is a simple mathematical form that is the closest possible to the geoid. The ellipsoid can be global (fitted to the terrestrial globe) or local (so as to fit the shape of the Earth at a given location as accurately as possible). Once assimilated to an ellipse, the surface of the globe can be subdivided by a network of lines enabling each point in space to be localized. From south to north, parallel lines indicate latitude, and from east to west, the meridians define longitude. Any place can thus be localized by way of its geographic coordinates in terms of latitude and longitude.

Figure 1.03 The shape of planet earth.

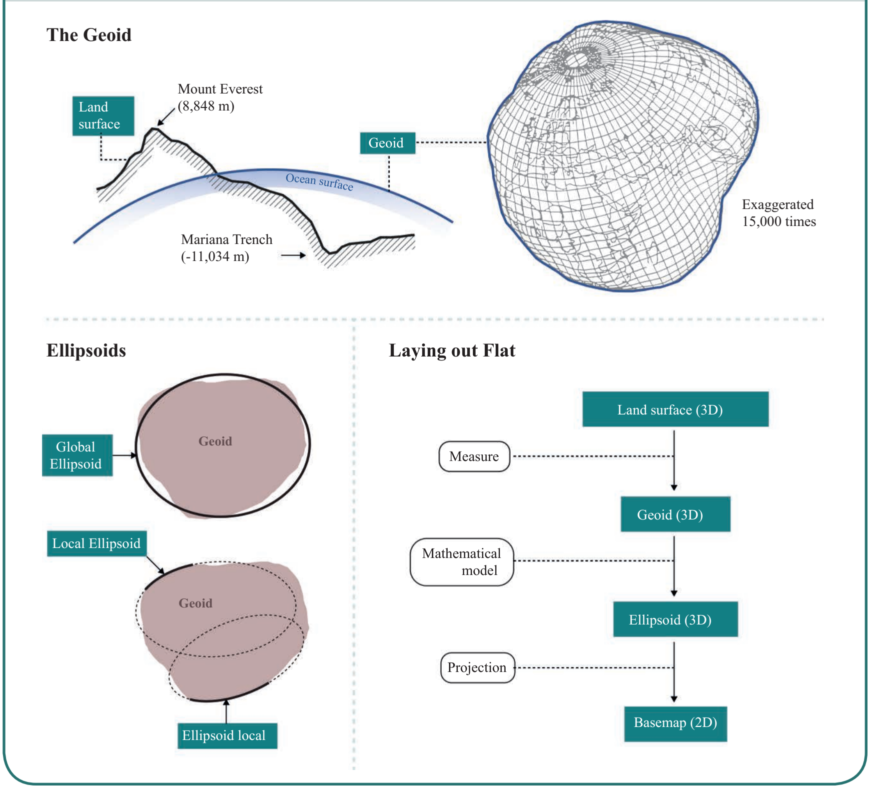
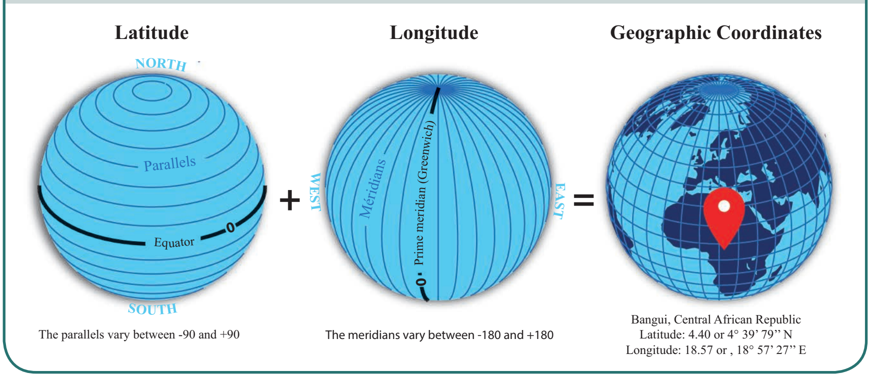


Figure 1.04 Geographic coordinates.



1.2.2 From Ellipsoid to Flat Surface

Projection is an operation that consists in converting a given ellipsoid into a flat surface. This mathematical operation can be performed in a number of ways. Thus, cartographic projections can be classified according to the way they are constructed.

Azimuthal projections are constructed by projecting points on the sphere onto a flat surface. The position of the point of contact between the plane and the sphere (center of the projection) naturally has an effect on the image projected.

Cylindrical projections are constructed by the projection of points on the sphere onto a tangent or secant cylinder. The developed (or unrolled) cylinder provides the flat surface.

Conical projections are constructed in the same manner by projecting points on the sphere onto a tangent or secant cone.

It follows that map projections can also be classified according to the type of distortion they produce.

Conformal projections preserve angles (and hence the shape of geographic objects). The parallels and meridians intersect at right angles, but the surface areas are altered as we draw away from the center of the map. This type of projection has the advantage of correctly representing the contours of countries, thus informing users of their real shape. These projections, long used in navigation, also have the advantage of enabling a linear itinerary to be traced on the map to follow a route. On these maps, the distortions of surface area increase the further, one gets from the center of the projection, which is not always the center of the map.

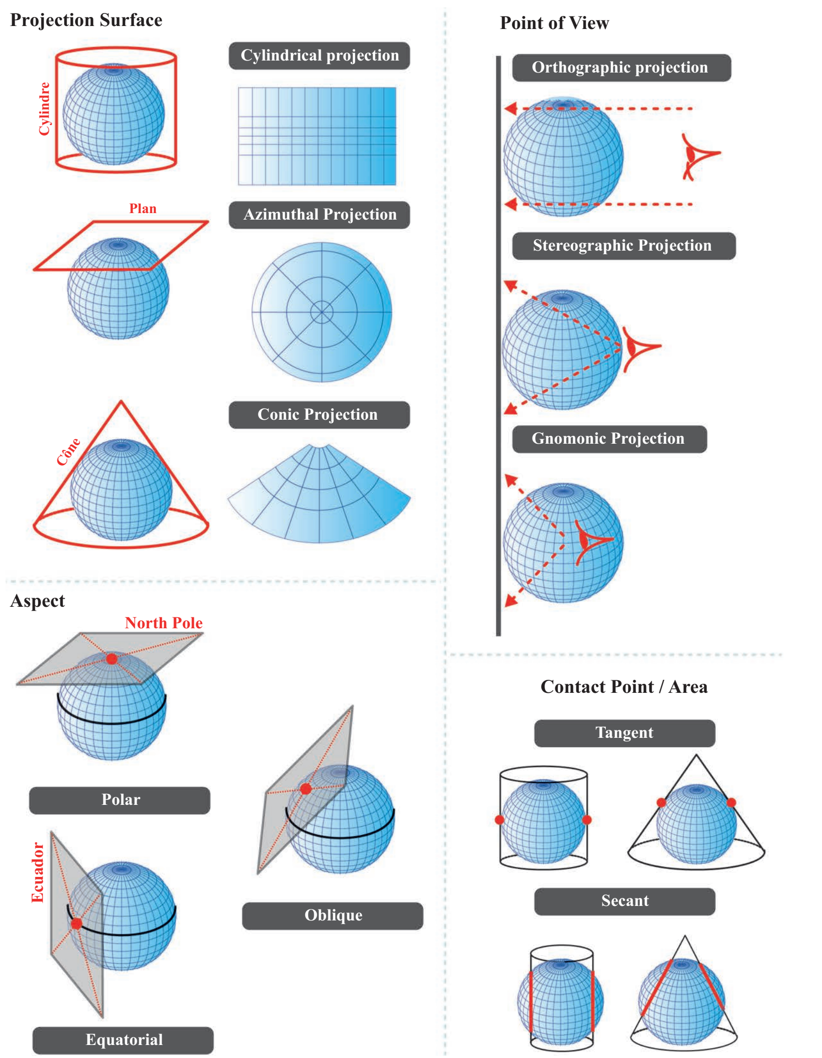
On the Mercator projection, for instance, Russia appears twice the size of Africa, while it is in fact half the size. Even more misleading, Latin America appears smaller than Greenland, while it is in fact nine times larger.

FOCUS: Elisée Reclus and His Geographic Utopia

Elisée Reclus (1830–1905), one of the pioneers of modern geography, was very critical of maps that, by construction, distort reality. According to this author, flat, projected maps can only mislead students by instilling false representations of the world. In addition to advocating their removal from classrooms, he launched into a wild project to construct a globe more than 139.4 yards in diameter for the 1900 Universal Exhibition. The globe, excessively expensive, was in fact never produced, although Reclus saw it as the only way to faithfully represent the Earth.

Equivalent projections preserve the relationships between surface areas, but the contours are markedly distorted on the edges of the map. On maps using this projection, the outlines of countries can be difficult to identify, which hampers the reading of the map. Nevertheless, the preservation of relationships between surface areas is valuable in thematic maps wherever the size of a country is relevant to the theme represented (for instance, population density).

Figure 1.05 Projections parameters.

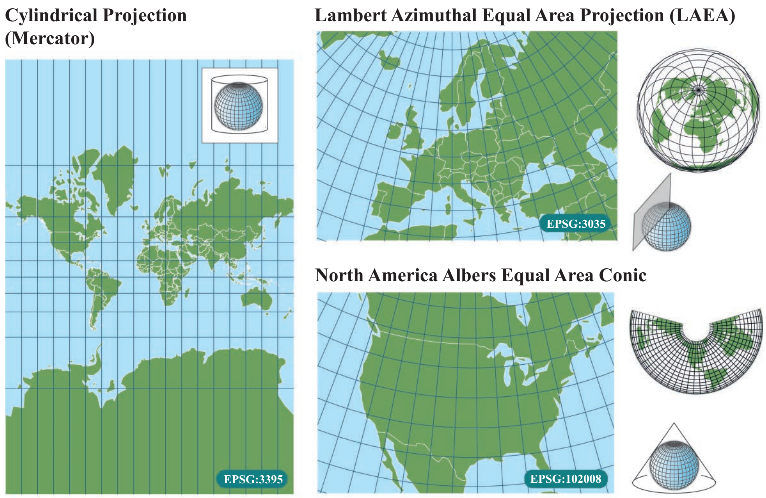


Equidistant projections display the actual distances from the center of the projection or along particular lines. But surfaces and shapes are not preserved.

Aphylactic – compromise – **projections** do not preserve angles, sizes, or distances, but attempt to compensate for these three distortions by way of a compromise, giving them the name of compromise projections.

The choice of the best projection is a central issue. However, at this stage the cartographer has numerous options. The answer to this is simple: everything depends on the scale!

Figure 1.06 Three important projections.



For example, In the USA, Albers equal-area conic is the typical projection for historical USGS (United States Geological Survey) map, it being a general-purpose low-distortion compromise for mid-latitude short and wide extents. This conical, conformal projection (retaining the shape of objects) can be implemented in several manners.

In Europe, there is likewise a reference cartographic projection, the Lambert azimuthal equal-area projection. As indicated by its name, it is an azimuthal projection (constructed from a tangent plane) that is also equivalent; that is, it preserves the relationships between surface areas. The drawback of this projection is therefore that it distorts the outlines of countries, but it has the advantage of preserving their surface areas, which is useful in thematic maps. Most of the basemaps issued in Europe use this projection.

To represent the world, there is a wide choice for cartographers. As the space to be represented is vast and cannot be viewed in its entirety because of the curvature of the globe, the cartographer can play on the scope for distorting maps to create one view of the world rather than another. While a ready-to-use basemap with a given projection is most often suitable, a cartographer who is conscious of the need to reflect on the message to be delivered needs to consider the issue of the projection. Is the projection on offer appropriate? Can the map be improved by switching to a different projection? The projection of a map is indeed an efficient means of expressing a message, as Amo Peters showed with his eponymous projection, which raised considerable debate (see "Focus" below).

When choosing a projection and all its attributes like center, edges, or orientation, the cartographer possesses numerous tools to perfect his/her message. The choice of the projection enables certain territories to be enlarged or reduced, which has an impact on the final bounding box of the map, i.e., the spatial extent. The choice of a particular center can be an effective way to express a viewpoint.

Figure 1.07 Each projection has its particular message.

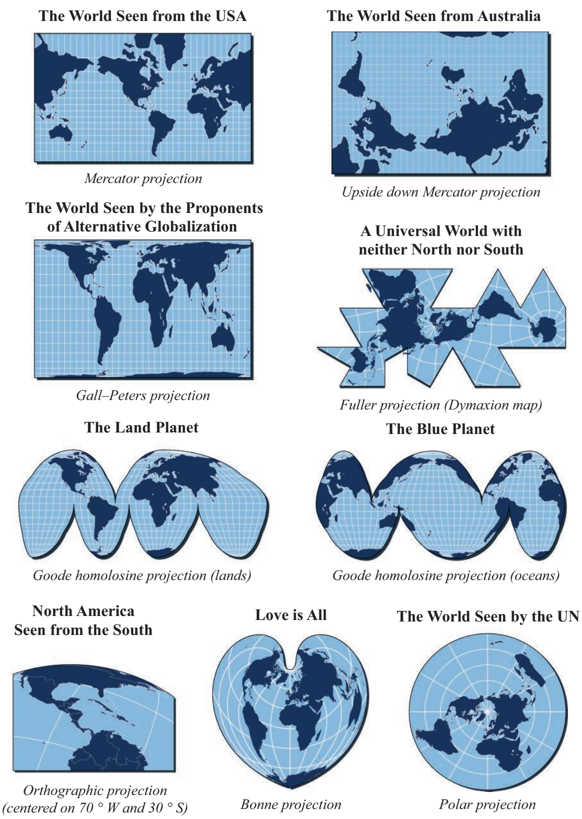
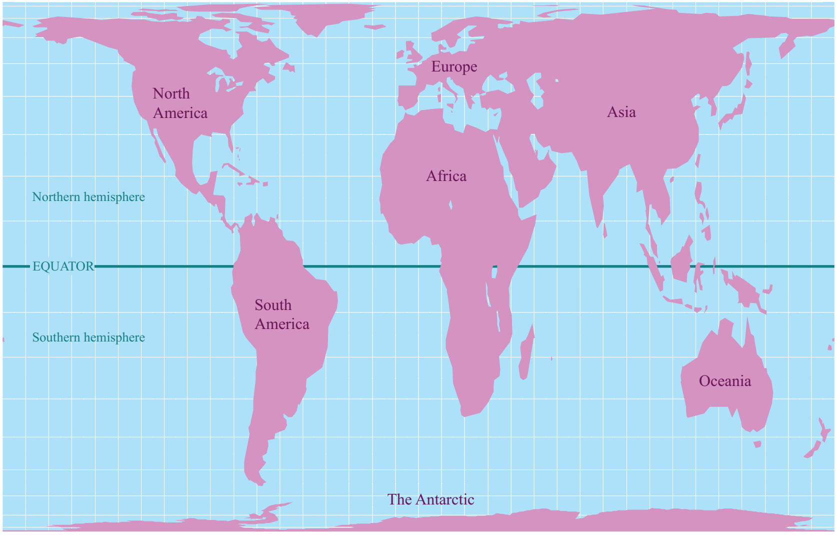
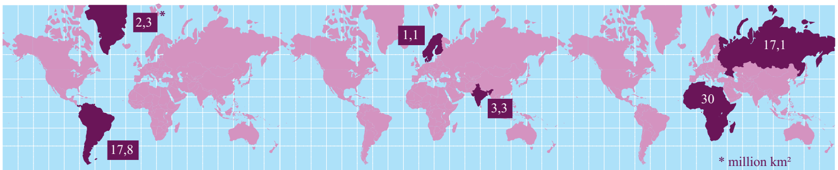


Figure 1.08 The Gall–Peters projection.

The Real Size of Continents



On the Mercator Projection:



South America appears smaller than **Greenland**, while it is in fact 9 times larger.

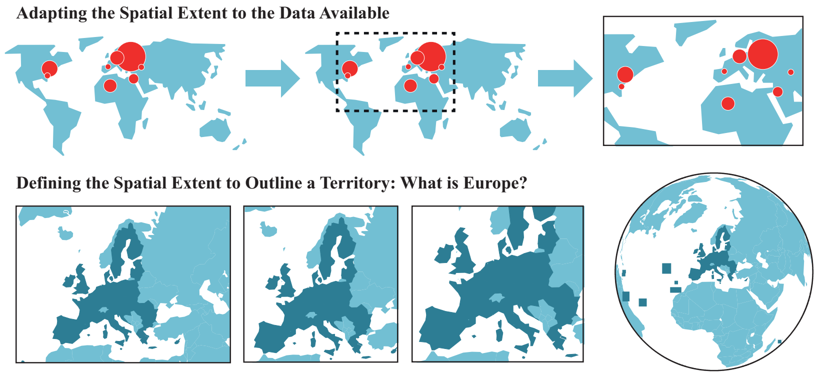
India appears to be the same size as **Scandinavia**, while in reality it is three times the size.

Africa appears to be the same size as **Russia**, while it is in fact twice the size.

1.3 SPATIAL EXTENT AND ORIENTATION

Designing a map first of all requires the decision of what to include and what not to include within the frame. As in photography, the choice of image composition is a means to transform the information, to orient the way it is read, or even to mislead. Choosing the spatial extent of a map can enable the exclusion of an element that, if present, would significantly alter the meaning of the map. It is also a way to define the center of the map (which only rarely corresponds to the center of the projection) or again a technique to maximize the status of the information to be represented. The right choice of cover also enables empty spaces on the map to be avoided.

Figure 1.09 The spatial extent of a map.



Choosing the spatial extent of a map means choosing where the representation of a territory starts, and where it ends. Should a map of Europe include Turkey, Ukraine, Lapland, or French Guyana? Where is the center of Europe? Should a map of the United States systematically include its remote territories in the Pacific Ocean?

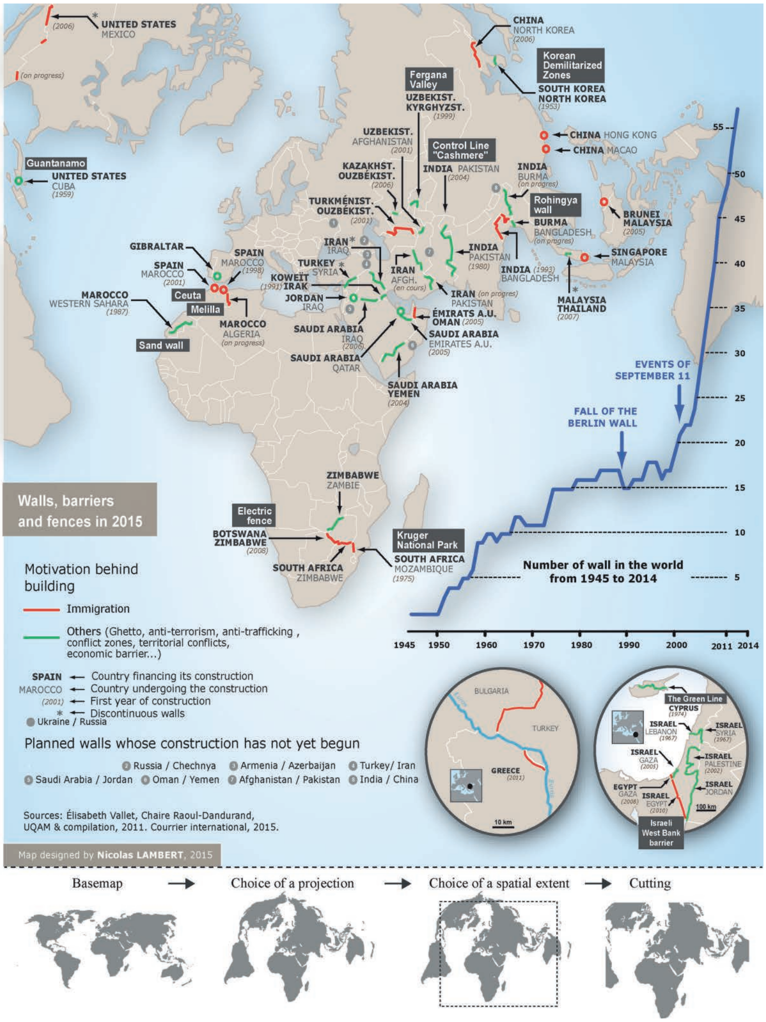
All in all, geographic observation and reasoning are always dependent on the size of the space considered (Lacoste, 1976).

The rotation (or orientation) of the basemap is also a way to influence the area covered and the general aspect of the map. Orientation in relation to the north is not a dogma that cannot be overcome. The habit has indeed evolved over time.

Although in Antiquity, the Greeks were already orienting their maps towards the north, by the Middle Ages, maps were oriented towards the East and the Levant. As for the Arabs, they oriented their maps southwards towards Mecca. Since the age of the great discoveries and the use of the magnetic compass for orientation, the orientation towards the north has taken precedence (Chinese sailors were using the compass by around the year 1000, well before the Arabs and European, and their maps were already oriented in relation to the north).

The orientation of maps in reference to the north is in no way compulsory, this being even more so in the case of thematic maps, where the way in which it is read and the manner in which the information is presented are essential. Nothing ties us to an obligation to comply with an orientation that is determined by the terrestrial magnetic field. While it may be more efficient to use a basemap of the type we are used to dealing with, it can also be interesting to choose an unusual viewpoint to serve an out-of-the-ordinary or controversial message. In this case, the orientation will be indicated on the map by an arrow enabling the reader to position himself. Finally, certain projections like the Fuller projection (see above) have neither north nor south.

Figure 1.10 Adapting the geographical extent to maximize the space represented.



Ever more numerous walls in a borderless world – this map shows the location of inter-state walls. While there were only a dozen in 1945, there are more than 70 today. The total length of the walls throughout the world reaches an impressive 40,000 km, the equivalent of the earth's circumference. Beyond the projection that enables all the territories concerned by this theme to be seen, the choice of the spatial extent of the map makes it possible to restrict "empty" spaces that are not useful to the understanding of the phenomenon.

Figure 1.11 North is not a dogma.

FOCUS: Did You Know?

It can be remarked that the word "NEWS" is made up of the letters N (north), E (east), W (west), and S (south).

FOCUS: Upside-Down Maps

In 1943, in order to denounce the Western view favored by world maps, the Uruguayan artist Joaquin Torres Garcia (1874–1949) designed a map of America reversing south and north. According to him, this reversal was needed to shake off the domination of countries in the north. Today, numerous Australian and Chilean world maps are presented "head down", vindicating this artist (e.g., Stuart McArthur's world map in 1979).

1.4 CARTOGRAPHIC GENERALIZATION

All maps are reduced reproductions of a portion of space. They therefore require a simplification of the representations. The reduction in scale and the minimum thickness of a line to remain visible on the map force the cartographer to simplify the contour, thus reducing the geometrical precision in order to enhance readability. A map developed with excessive detail in the contours, far from adding precision, risks "obfuscation" when compressed or downsized. This distracts from the main message of the map.

Cartographic generalization has four objectives:

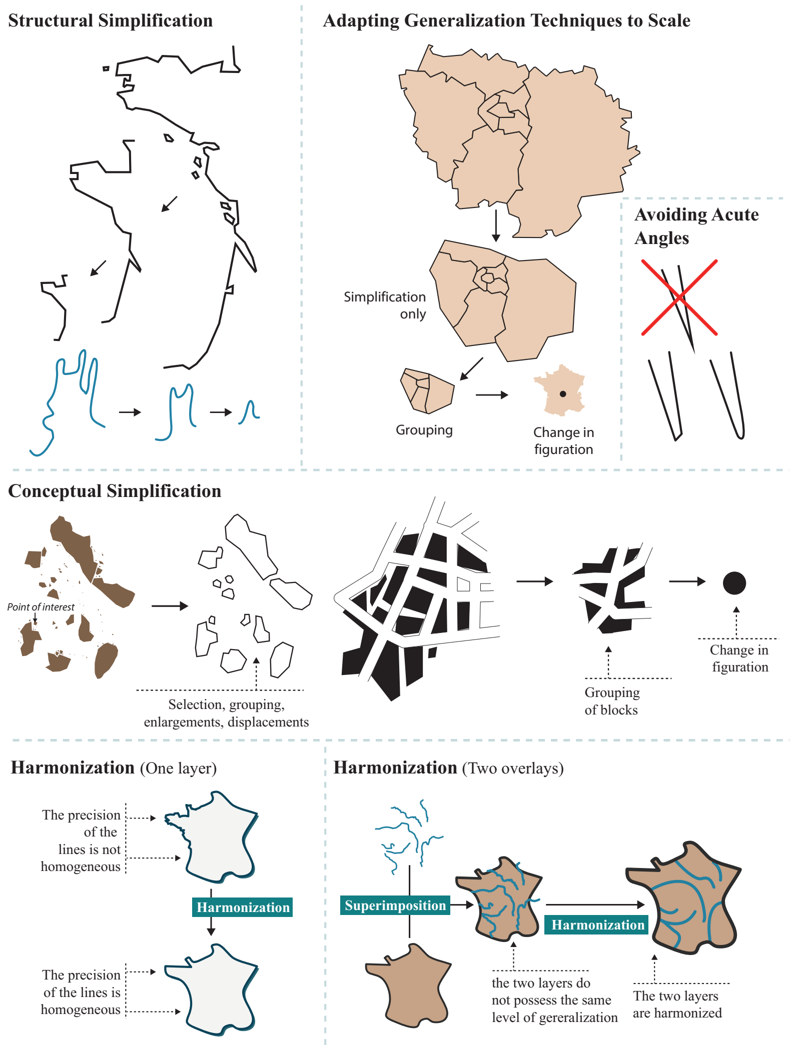
1. A **pragmatic objective:** enhancing the readability of the map by avoiding "obfuscation".
2. A **scientific objective:** removing any graphic overload (noise) that might hamper the message of the map.
3. A **technical objective:** reducing data on the basemap by reducing the number of coordinates stored and memorized so as to use it effectively in computerized applications.
4. An **aesthetic objective:** representing a territory according to a predefined graphic style.

Generalization, which is an essential step in map development, is difficult to automate. It consists in a simplification of lines while at the same time preserving the general aspect of the territory so that it remains identifiable. The generalization procedure entails three main operations:

- **Selection** is choosing the graphic elements to be shown on the map. This operation addresses the generalization process in two ways: choosing categories of data to be represented (one shows only roads but not railroads) and/or choosing the amount of information within categories (should the outlines of islands or enclaves smaller than a certain surface area be retained?).
- Producing a simplified form: the geometric operation of **simplification** of the lines to be traced (**structural** sketch diagram). This can also be a **conceptual** sketch diagram when it includes elements of interpretation and manual choices (grouping of objects, enhancement, exaggeration, smoothing, grouping, displacement, symbolization, etc.).
- **Harmonization**: this is an operation of general harmonization of the basemap to obtain a comparable level of generalization at any point on the map.

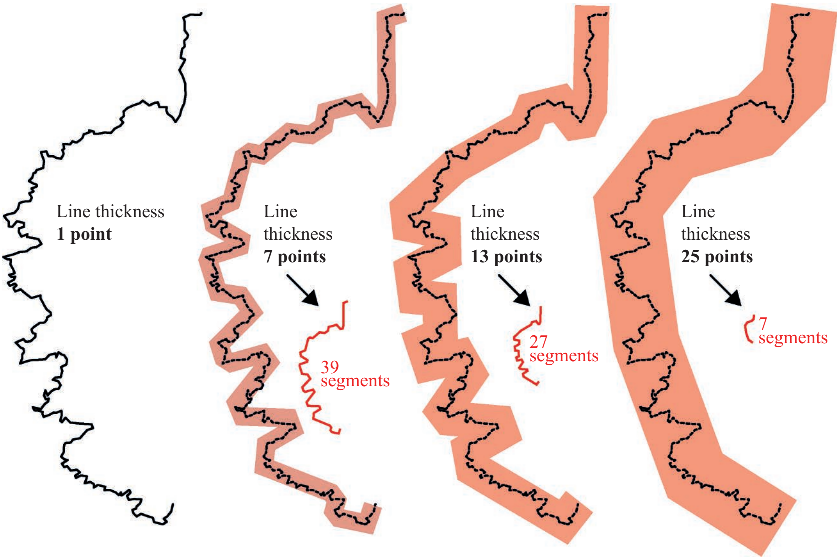
Even if the generalization process can be partly automatic, a well-generalized map is unlikely to be achieved without a manual stage. This is no doubt an advantage, because the basemap and its level of generalization are among the elements available to the cartographer to efficiently express the message intended. It is possible to draw away from the precise localization of objects to facilitate readability of the map. Thus, the cartographer can move certain characteristic lines or forms so as to correct graphic incompatibilities, group certain smaller characteristics into larger units, remove certain objects and enlarge others, or change the graphic representations. Thus, generalization

Figure 1.12 Cartographic generalization.



makes it possible to reduce or delete certain elements considered to be unimportant, or conversely to focus on certain locations that are important for the intended message. Choosing the level of generalization expresses at least part of the message.

Figure 1.13 Structural simplification.



How can a basemap be simplified manually? The colored band shows the generalized line for the western coast of Corsica. By varying the scale and/or the width of the line drawn, the original line (in black) is simplified to a greater or lesser degree. The segments reduce in number with the simplification.

Figure 1.14 Generalization, human choices.

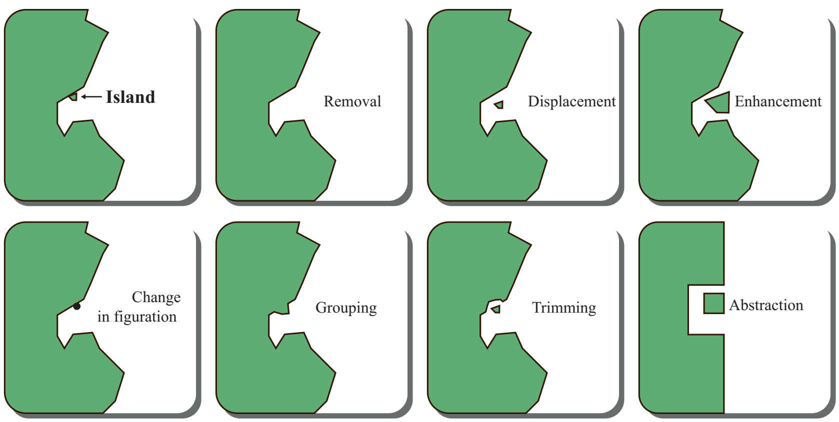


Figure 1.15 Graphic styles: curves.

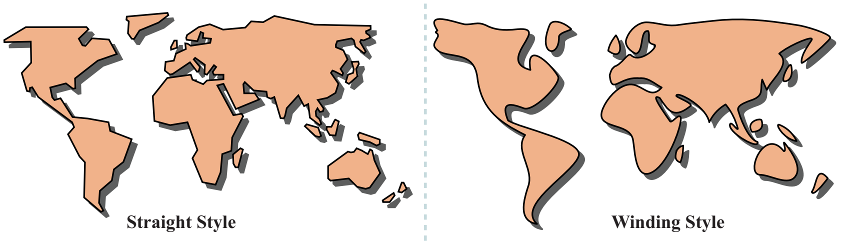
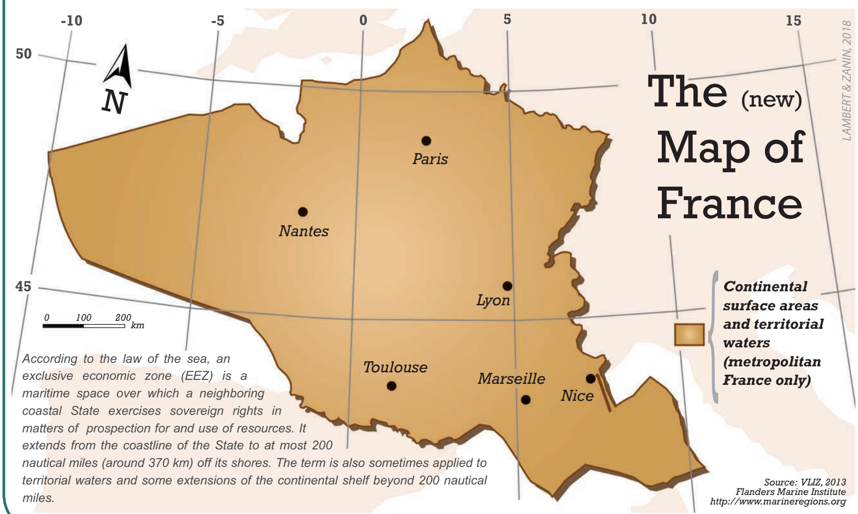


Figure 1.16 New map of France.



Review your geography – France is not what you thought it was! Here is its real aspect....

What in fact is lacking on our usual maps? No less than the sea. It is true that few people live on the sea. But does this justify representing only land masses on maps? Maybe but...other spaces on Earth are uninhabited – mountains above the snowline, deserts, and polluted sites – but would we consider removing them from our maps? No, we would not. So why do we wittingly exclude such a large portion of national territory, which for a human population that will soon number nine billion will gain increasing importance? Today we fish in the sea, they are fish farms, we navigate on the sea, we use the sea to produce energy, we transport our goods by sea, we find our raw materials there – and these are all elements of human activity. Why should we amputate France of one of its important components on our maps? So here is the new map of France, as it should be found in geography textbooks. For these are the real boundaries of France, in its terrestrial and maritime dimensions. Something we need to "get our heads around".

FOCUS: The Subliminal Geometry of the Basemap

Beyond the scientific and technical aspects, the basemap can also conceal a subliminal message. In Patrick Schulmann's French film *P.R.O.F.S.* (1985), the history and geography teacher Charles Max (sic) describes two maps hanged in the classroom: "See how the outline of a State reflects the spirit of the State. A primitive spirit (showing a map of the USA)! Look at these straight lines, arbitrary and reactionary. Here, on the other hand (showing a map of the USSR) look how the borders of the States are fitted to the mountains and the rivers, in other words to man. This shows a spirit of justice and generosity. Even the coastline! See how gentle the borders are (on the map of the USSR). See here (on the map of the USA) how indented and completely aggressive they are".

This film excerpt is a funny illustration of the meaning that can be put in a mere basemap, even if it's done in poor faith. ➲ *https://www.youtube.com/watch?v=58qi6G7lV9E*

1.5 THE SPATIAL SUBDIVISIONS

From a geometric point of view, the grid (or spatial subdivisions) refers to a strict partition (without overlap or blurring) of a geographic area into contiguous units whose shape and size can be regular or irregular. It is a partition of the space whose elementary pieces are polygons of shapes and surfaces that are often heterogeneous, interlocking each other like puzzle pieces (John Spilsbury, the inventor of the puzzle in 1766 was a geographer).

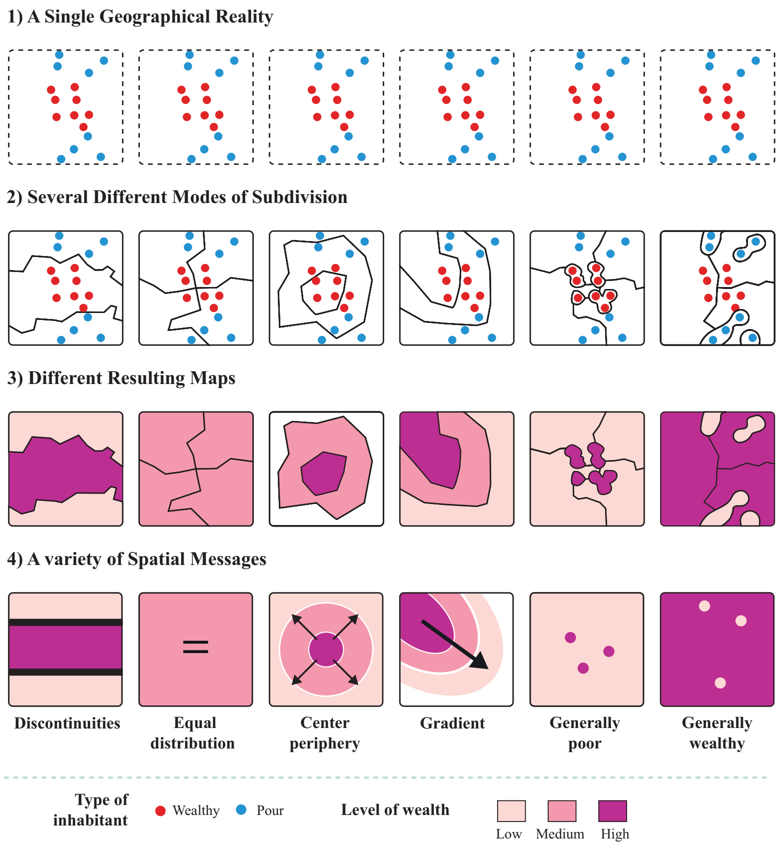
Beyond the mere administrative subdivision of space, spatial subdivision systems are also (and above all) reading grids or subdivisions enabling a reality to be captured. They provide a mesh or "canvas" for comprehension and analysis, based on the simplification and generalization of information. They are tools for constructing knowledge. Grids are territorial filters in which each unit provides information for the understanding of the spatial phenomenon analyzed. Thus the statistical, cartographic and modeling results depend on the grid or type of subdivision chosen. A change in size, shape, or positioning of the different elements, even if minute, will affect not only the statistical results, but also their cartographic representation.

Several studies, referred to the acronym MAUP (Modifiable Areal Unit Problem), show that the subdivision of space adopted affects the reading of the spatial organization of a phenomenon, sometimes very markedly. The size of the territorial units also has an impact on the reading of the information, in particular because certain statistical processing operations, upstream of their representation, are directly influenced by this parameter. For instance, the correlation between two phenomena can be significant using one areal unit, but not using a different one. Likewise, if a certain form of spatial organization can be perceived on one map using a given unit, it will not necessarily appear using another. The use of a subdivision made up of administrative units of very different sizes is genuinely problematic: it amounts to constructing a map representing non-comparable geographic units in a single image.

FOCUS: The MAUP

The MAUP concept was proposed by Openshaw (1978) and Taylor (1979) to refer to the influence of spatial subdivisions (scale effects and zone effects) on the results of statistical calculations or modeling procedures.

Figure 1.17 The type of subdivisions chosen forms a cartographic filter.

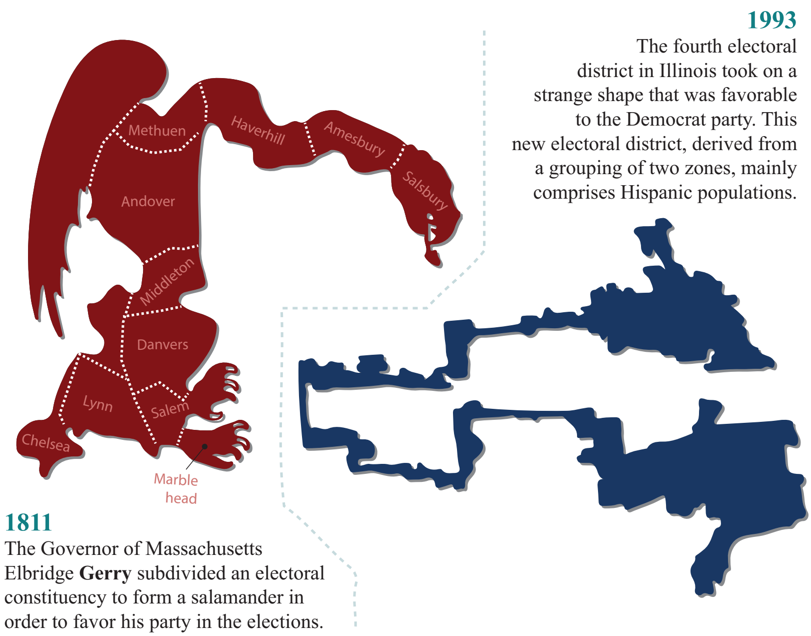


It is therefore fundamental to take this into account when interpreting cartographic images derived from these irregular subdivisions (to manage the MAUP issue, cartographic solutions are proposed in Chapter 7 of this handbook).

FOCUS: Subdivision and Gerrymandering

Far more than a means of perceiving and analyzing spatial structures, the system of subdivision used is also part of a power game. The person possessing the power to define the subdivision of space can draw advantage from it. For instance, the North Americans can indulge in gerrymandering. This practice consists in subdividing the electoral constituencies in such a way that a particular candidate is favored. The term is derived from the name of Governor Elbridge Gerry, who in 1811 plotted out an electoral constituency in the shape of a salamander. While this example is something of a caricature, even when electoral subdivisions appear balanced and fair they are never without significance.

Figure 1.18 Electoral gerrymandering.



Quiz

- What is an ellipsoid?
- What is the MAUP?
- What are the three operations involved in generalization?
- What is an equal-area projection? A conformal projection? An aphylactic projection?
- Why are maps oriented in relation to the north?
- Why are the differences between vector and raster?
- Why does the choice of the spatial extent have an effect on the representation?

Bibliography

Andrienko, Gennady, and Andrienko, Natalia. (2006). *Exploratory Analysis of Spatial and Temporal Data*. Berlin: Heidelberg, Springer-Verlag.

Béguin, Michèle, and Pumain, Denise. (2014). *La représentation des données géographiques. Statistique et Cartographie* (5th ed.). Paris: A. Colin.

Bertin, Jacques. (1967). *Sémiologie Graphique. Les diagrammes, les réseaux, les cartes.* Paris: La Haye, Mouton, Gauthier-Villars. (1973) 2nd ed.; (1999) 3rd ed. 2e édition: 1973, 3e Paris: EHESS.

Bertin, Jacques. (1983). *Semiology of Graphics* (William J. Berg, Trans.). Madison, WI: University of Wisconsin Press.

Borges, Jose-Luis. (1982). *L'auteur et autres textes* (3rd ed.). Paris: Gallimard.

Brewer, Cynthia A. (1994). Color use guidelines for mapping and visualization. In Allan M. MacEachren and D.R. Fraser Taylor (Eds.), *Visualization in Modern Cartography* (pp. 123–147). New York: Pergamon.

Brewer, Cynthia A. (2005). *Designing Better Maps: A Guide for GIS Users.* Redlands, CA: ESRI Press.

Brotton, Jerry. (2014, reprint). *A History of the World in Twelve Maps*. London, UK: Penguin Books.

Brunet, Roger. (1990). *La carte, mode d'emploi.* Paris: Reclus-Fayard.

Brunet, Roger, Ferras, Robert, and Théry Henri. (1992). *Les mots de la géographie, dictionnaire critique*. Paris: Reclus, La Documentation française.

Campbell, John. (2001). *Map Use and Analysis* (4th ed.). New York: McGraw-Hill.

Cartwright, William, Milelr, Suzette, and Pettit, Christopher. (2004). Geographical visualization: Past, present and future development. *Spatial Science*, 49, 5–36.

Cartwright, William, Peterson, Michael P., and Gartner, Georg (Eds.). (2007). *Multimedia Cartography* (2nd ed.). New York: Springer-Verlag.

Cauvin, Colette, Escobar, Francisco, and Serradj, Aziz. (2008). *Cartographie Thématique.* Vol. 1–5. Paris: Information géographique et Aménagement du territoire, Hermes, Lavoisier.

Cauvin, Colette, Escobar, Francisco, and Serradj, Aziz. (2010a). *Cartography and the Impact of the Quantitative Revolution.* Vol. 2, London, UK: Iste Ltd, Wiley & sons, Inc.

Cauvin, Colette, Escobar, Francisco, and Serradj, Aziz. (2010b). *New Approaches in Thematic Cartography.* Vol. 3. London, UK: Iste Ltd, Wiley & sons, Inc.

Churchill, Winston. (1946). The sinews of peace*. Iron Curtain Speech*, 1946, March 5th. Fulton. https://www.youtube.com/watch?v=X2FM3_h33Tg.

Claval, Paul. (2011). Histoire de la Géographie. *Que sais-je?* n°65. https://www.cairn.info/histoire-de-la-geographie--9782130586524.htm

Cleveland, William S. (1994). *The Elements of Graphing Data*. Murray Hill, NJ: ATT Bell Laboratories.

Crampton, Jeremy W. (2001). Maps as social constructions: Power, communication and visualization. *Progress in Human Geography*, 25(2), 235–252.

Crampton, Jeremy W., and Krygier, John. (2006). An introduction to critical cartography. *ACME: An International E-Journal of Critical Geographies*, 4(1), 11–33.

Dent, Borden D., Torguson, Jeffrey, and Holder, Thomas W. (2009). *Cartography: Thematic Map Design* (6th ed.). New York: McGraw-Hill Higher Education.

DiBiase, David. (1990). Visualization in the earth science. *Earth and Mineral Science Bulletin*, 59(2), 13–18.

Dodge, Martin, McDerby, Mary, and Turner, Martin. (Eds.). (2008). *Geographic Visualization: Concepts, Tools, and Applications*. Hoboken, NJ: Wiley.

Dorling, Danier, and Fairbairn, David. (1997). *Mapping: Ways of Representing the World*. New York: Prentice Hall.

Dorling, Denis. (1993). Map design for census mapping. *The Cartographic Journal*, 30(2), 167–183.

Dorling, Denis. (1994). Cartograms for visualizing human geography. In D.J. Unwin and H.M. Hearnshaw (Eds.), *Visualization in Geographic Information Systems* (pp. 85–102). London, UK: Wiley & sons, Inc.

Edney, Matthew, H. (2005). *The Origins and Development of J. B. Harley's Cartographic Theories, Cartographica Monograph* 54, *Cartographica* 40, nos. 1 & 2. Toronto: University of Toronto Press.

Field, Kenneth. (2018). *Cartography*. New York: ESRI Ed.

Goodman, Nelson. (1972). *Problems and Projects*. Indianapolis: Bobbs-Merrill.

Gould, Peter, and Bailly, Antoine. (1995). *Le pouvoir des cartes – Brian Harley et la cartographie*. Paris: Economica.

Grasland, Claude, and Madelin, Malika. (Eds.). (2007). *The Modifiable Area Unit Problem, Final Report of Espon Project 3.4.1*. Luxembourg: The ESPON Monitoring Committee.

Goodchild, Michael F. (1997). A GIS perspective. In *Proceedings, Atlantic Institute Think Tank V: Global Educational Paradigms in Geomatics/Geoinformation* (pp. 77–82). Paris: Ecole Nationale des Sciences Geographiques.

Goodchild, Michael F. (2008). Statistical perspectives on geographic information science. *Geographical Analysis*, 40(3), 310–325.

Harley, J. Brian. (1989). Deconstructing the map. *Cartographica,* 26(2), 1–20.

Harley, J. Brian. (2001). *The New Nature of Maps: Essay in the History of Cartography* (Paul Laxton, Ed.; Introduction by J.H. Andrews). Baltimore, MD: Johns Hopkins University Press.

Harley, J. Brian, and Woodward, David. (Eds.). (1987). *The History of Cartography.* Chicago, IL: The University of Chicago Press.

Harrower, Mark. (2003). Tips for designing effective animated maps. *Cartographic Perspectives*, 44, 63–65, 82–83.

Harrower, Mark. (2009). Cartographic Animation. In Rob Kitchin and Nigel Thrift (Eds.), *International Encyclopedia of Human Geography*. Oxford, UK: Elsevier.

Harvey, Francis. (2008). *A Primer of GIS: Fundamental Geographic and Cartographic Concepts*. New York: Guilford Press.

International Cartographic Association. (1973). *Multilingual Dictionary of Technical Terms in Cartography*. Wiesbaden: Franz Steiner.

Jacob, Christian. (1992). *L'empire des cartes: Approche théorique de la cartographie à travers l'histoire*. Paris: Albin Michel.

Kaiser, Ward L., and Wood, Denis. (2001). *Seeing Through Maps: The Power of Images to Shape Our World View*. Amherst, MA: ODT, Inc.

Korzybski, Alfred. (1933). *Science and Sanity. An Introduction to Non-Aristotelian Systems and General Semantics* (pp. 747–761). Lancaster, PA: The International Non-Aristotelian Library Pub. Co.

Kraak, Menno-Jan. (2007). Cartography and the Use of Animation. In William M. Cartwright, Michael Paterson, and Georg Gartner (Eds.), *Multimedia Cartography* (pp. 317–326). New York: Spinger-Verlag.

Kraak, Menno-Jan, and Brown, Allan. (Eds.). (2001). *Web Cartography: Developments and Prospects*. New York: Taylor & Francis.

Kraak, Menno-Jan, and Ormelling, Ferjan. (2010). *Cartography: Visualization of Geospatial Data* (4th ed.). New York: Prentice Hall.

Krygier, John, and Wood, Denis. (2005). *Making Maps: A Visual Guide to Map Design for GIS*. New York: Guilford Press.

Lacoste, Yves. (1976). *La géographie, ça sert, d'abord, à faire la guerre*. Paris: Maspero.

Lambert, Nicolas and Zanin, Christine. (2016) *Manuel de cartographie – Principes, méthodes, applications (french).* Paris: Armand Colin.

Lambert, Nicolas and Zanin, Christine. (2019) *Mad Maps: L'atlas qui va changer votre vision du Monde (french).* Paris: Armand Colin

Linford, Chris. (2004). *The Complete Guide to Digital Color: Creative Use of Color in the Digital Arts*. New York: Harper Collins.

Mac Eachren, Alan M. (1991). The role of maps in spatial knowledge acquisition. *The Cartographic Journal*, 28, 152–162.

Mac Eachren, Alan M. (1994a). *Some True with Maps: A Primer on Symbolization and Design.* Washington, DC: Association of American Geographers.

Mac Eachren, Alan M. (1994b). Visualization in modern cartography: Setting the agenda. In Alan M. MacEachren and D.R. Fraser Taylor (Eds.), *Visualization in Modern Cartography* (pp. 1–12). Oxford, UK: Elsevier.

Mac Eachren, Alan M. (1995). *How Maps Works: Representation, Visualization, and Design.* New York: Guilford Press.

Mac Eachren, Alan M., and Taylor, D. R. Fraser (Eds.). (1994). *Visualization in Modern Cartography*. New York: Pergamon.

Mathian, Hélène, and Sanders Lena. (2014). *Spatio-temporal Approaches: Geographic Objects and Change Process*. Paris: ISTE Ltd.

Monmonier, Mark. (1977). *Maps, Distortions, and Meaning*. Washington, DC: Association of American Geographers.

Monmonier, Mark. (1996). *How to Lie with Maps* (2nd ed.). Chicago, IL: University of Chicago Press.

Monmonier, Mark. (2004). *Rhumb Lines and Map Wars: A social History of the Mercator of Projection.* Chicago, IL: University of Chicago Press.

Muehrcke, Philip C., and Muehrck, Juliana O. (1992). *Map Use: Reading, Analysis, Interpretation* (3rd ed.). Madison, WI: JP Publications.

Openshaw, Stan, and Taylor, Peter, J. (1981). The Modifiable Areal Unit Problem. In N. Wrigley and R.J. Bennett (Eds.), *Quantitative Geography: A British View*. London, UK: Routledge & Kogan Page.

Peuquet, Donna J. (2002). *Representations of Space and Time*. New York: Guilford Press.

Peterson, Michael P. (2003). *Maps and the Internet*. New York: Elsevier.

Reclus, Elisée. (1903). On Spherical Maps and Reliefs. *The Geographical Journal*, 22(3), 290–293.

Rekacewicz, Philippe. (2014). Entre imaginaire et réalité: l'intention cartographique. *Revue 303* n°133. https://www.editions303.com/le-catalogue/numero-133-cartes-et-cartographie/

Robinson, Arthur H. (1952). *The Look of Maps: An Examination of Cartographic Design*. Madison: University of Wisconsin Press.

Smith, Adam. (1776). An Inquiry into the Nature and Causes of the Wealth of Nations. Ed. W. Strahan and T. Cadell, London

Stewart, John Q. (1942). Measure of the influence of a population at a distance. *Sociometry*, 5(1), 63–71.

Tobler, Waldo. (1973). Choropleth Maps without Class Intervals. *Geographical Analysis*, 5, 262–265.

Tobler, Waldo. (2004). Thirty-Five Years of Computer Cartograms. *Annals of the Association of American Geographers*, 941(1), 58–73.

Tyner, Judith A. (1992). *Introduction to Thematic Cartography*. Englewood Cliffs, NJ: Prentice Hall.

Tyner, Judith A. (2005). Elements of Cartography: Tracing 50 Years of Academic Cartography. *Cartographic Perspectives*, 51, 4–13.

Tyner, Judith A. (2010). *Principles of Map Design*. New York: Guilford Publications.

Wood, Denis, and Fels, John. (1992). *The Power of Maps*. New York: Guilford Press.

Zanin, Christine, and Tremelo, Marie-Laure. (2003). *Savoir-faire une carte: Aide à la conception et à la réalisation d'une carte thématique univariée*. Paris: Belin.

Zelevansky, Lynn. (2008). *An Atlas of Radical Cartography*. Los Angeles, CA: Journal of Aesthetics and Protest Press.