Anatomy of a map

The mapped area and associated map pieces together make the map.

Maps tend to share common components which each perform a discrete function and, collectively, make the map. There are two basic components—the mapped area and the marginalia, or the additional map pieces. Not all map pieces will be required on every map. The type of map will lead to different pieces as will the use conditions and the medium of delivery. Maps produced as part of a national map series will have consistent pieces but a one-off map in a book or on a poster may have relatively few.

The term map marginalia can be misleading since the various pieces are often positioned within the mapped area itself. Certainly, this is more common for digital maps which do not necessarily have formal layouts. Many of the map pieces might be located behind buttons, tabs, or click events instead, which helps to create an uncluttered display.

Inset or locator maps help orient the map reader unfamiliar with the geography of an area. Sometimes the location of the map isn’t obvious or the map will likely be used by people unfamiliar with the area. Providing a small contextual map that shows the extent of the main mapped area can be extremely helpful. This consideration equally applies to digital maps. The extent of the map may change as a map reader zooms in and out but it remains a useful map piece nevertheless. Alternatively, an inset map may provide a larger scale version of a part of the main map, sometimes used if the data in that area is particularly dense or congested. Insets can also be used to bring disparate parts of the same geography into a convenient view. For instance, thematic maps of the United States often place Alaska and Hawaii in insets because of their detachment and remoteness to the contiguous Lower 48 states.

See also: Form and function | Data arrangement | Functional cartography
Branding

Branding provides structure and certainty in a map and related products, usually specific to particular publishers or organisations.

The work of many cartographers demands them to apply design and styles according to a set of specifications developed by an organisation. These specifications give structure and a design framework that clearly situate maps and associated products within the same visual family. One only has to consider the branding used by major cities for their metro rail services to see this at work. Or, think of the different designs that characterise national map series.

Branding breeds familiarity that builds awareness and loyalty. People become comfortable with brands, which enables them to immediately associate products with places and the organisation that publishes them. Branding in commerce is designed to sell product, and it’s actually a similar concept for cartography. We want to sell a brand, part of which is the cartography that supports the brand. However, consumers have little choice in riding a city’s metro because there is only one so why does branding exist? It’s done to provide wider exposure and to bring coherence to all the various elements of the design—maps, signage, colours, and typography.

Communication is the essence of good branding as organisations blend design components to create a whole. Large branding guidelines often accompany designs, and copyrights exist to protect such branding. National mapping agencies also apply branding to their products and we can easily recognise an Ordnance Survey map from one made by swisstopo, National Geographic, or USGS. They have a look and a feel that generations become familiar with.

Branding goes beyond look and feel. Maps often use specific colours, symbology, and fonts that help define them but there will be other clear branding characteristics. The structure of a page, its layout, or the marginalia will all be consistent. Logos are also important and often act as the focal point for a brand. Think of the NASA logo, or the London Underground Roundel or any famous logo. They become iconic and lead the branding in which maps might also be situated.

Branding is usually related to an organisation but for the independent cartographer working on one-off projects, branding can also be useful. Developing a style that people identify with can lead to a brand identity. Does the subject matter relate to a certain style or type of map for instance? In fact, do you make maps that are similar in scope which might suit a wider brand identity? Will the reader be expecting a particular look and feel because of who made the map? Do you need to think about marks, logos, and pictorial components that will allow the reader to inherently and more immediately understand the map and its information as it relates to a wider brand initiative?

Brands have to be self-explanatory. That might not happen overnight but there comes a point where readers will expect a certain look and feel. If they are challenged by the unfamiliar, it becomes an impediment to their ability to retrieve information and can be jarring and uncomfortable.

It’s often worth exploring the brand guidelines of many organisations. For instance, the brand guidelines and standards manuals of Transport for London (TfL 2014) and the New York City Transit Authority (Vignelli and Noorda 1970) clearly illustrate the thinking behind their approach to very different subway map designs. They are both synonymous with their cities and help to brand the city itself.

As an independent mapmaker, there’s a fine line between persisting with a particular map style and deciding when to change tack. Making all your maps in the same style will ultimately lead to a sense of over familiarity with your work. Your audience may tire of seeing the same design ethos. There’s no magic recipe for getting this balance right but being aware of the impact of branding, style, and your audience’s capacity for seeing new approaches is useful.

Opposite: My own arm getting branded with a likeness of my favourite map.
Colour deficiency

Designing for colour-deficient vision leads to the use of particular colour palettes.

On average, approximately 4 percent of the population has some form of impairment in their colour vision compared with the rest of the population. This is more pronounced for men, with nearly 10 percent, than women and severity differs between people. Since colour plays such an important role in communicating map detail, there are consequences for ignoring colour deficiencies. Colour deficiencies affect people’s abilities to see hues in the same way. The perception of lightness remains unaltered, and this can assist in the selection of colours that accommodate alternative ways of seeing.

Colour-blindness is either total or partial. Total colour-blindness (monochromacy) is the rarest form, which results in a monochrome image being seen. Most common is red-green colour-blindness, the main forms of which are deuteranopia and protanopia. Less common is blue-yellow colour-blindness, the main form of which is tritanopia. Each inherited type of colour-blindness results in different cones in the eye having mutated forms of pigment that renders them unable to process specific wavelengths of visible light. Effectively, people with different vision impairments see the electromagnetic spectrum differently, and this leads to an ambiguity in colour perception, slower recognition, and less successful map search tasks.

Improvements in clarity can be made by using unambiguous colour combinations, supplementary visual variables, and annotation. Selecting appropriate colours can be achieved by using colour-blind safe palettes, many of which are published as colour-blind safe charts. Avoiding known colour combinations and increasing saturation and value between symbols can also help differentiate, particularly points and lines that are harder to recognise. Ensuring a good level of contrast between a map’s figural components and background also helps.

The following pairs of hues are considered a safe set that most people with colour impaired vision are able to see:
- red and blue
- red and purple
- orange and blue
- orange and purple
- brown and blue
- brown and purple
- yellow and blue
- yellow and purple
- yellow and grey
- blue and grey

All sequential, diverging, and qualitative colour schemes can be adjusted to be read by those with colour-deficient vision. A good colour scheme always uses variations in lightness which naturally accommodates colour-deficient vision. Adjusting colours to a safe palette or using the pairs of colours above provides added clarity.

Qualitative colour schemes can be harder to design since many standard conventions will be hard to see. Additionally, it’s common practice to design such schemes to be perceptually similar in lightness to avoid overemphasis of one feature type. Choosing hues that cause fewer difficulties and carefully adjusting lightness give a good separation while also remaining suited to normal vision.

There are a number of useful web tools available that can be used to choose colours to accommodate deficiencies. Alternatively, test your map by filtering it to show how people with particular colour deficiencies will see the map. Tools are listed in the back matter.

See also: Constraints on map colours | Perceptual colour spaces | Seeing
Colour deficiency

Answers: Africa, Australia, India, South America, Japan, Mexico, British Isles, Australia,
Data classification

Data classification processes raw data into something that, when mapped, teases out essential characteristics for display.

Data classification is the process of transforming raw data into classes that can each be given a unique symbol on a map. It is important in thematic mapping where the primary focus is to group quantitative values by similar characteristics or qualitative values by type. It is equally important in topographic mapping where, for instance, elevation is classified to derive contour values.

Possibly the most important decision in classification is choosing how many classes to divide the data into. For 100 individual values in a dataset, the maximum number of classes would be 100, and the minimum number of classes would be one, in which the class interval encompasses all values. Clearly these extremes are inappropriate but the decision has to be made somewhere along the scale of 1–100. Convention suggests five or six classes are appropriate simply because this yields a number of classes that can be effectively symbolised so map users can discern difference between symbols. It’s a good default to guide you. Less than five, and you will lose a lot of detail. More than six, and readers lose the ability to identify perceptually different symbols on the map.

The antithesis of a classified map is an unclassified map where, in a dataset of 100 unique values, you would require 100 unique symbols to represent each value. This is graphically possible but cognitively problematic since it requires the reader to do a considerable amount of examining to decipher even basic patterns. Grouping the 100 values into classes gives you fewer unique symbols and aids the map reader in seeing the message. The task is not necessarily easy since by grouping data into classes you are generalising the data and that inevitably means losing detail. You should apply classification schemes that find a balance between effectively summarising the salient characteristics of the data but which can also be depicted cartographically. The retention of detail and ability to see outliers does make unclassed maps useful in that regard.

There are many different methods for classifying data. None are universally perfect but these questions are useful to ask:

- Does the scheme consider the distribution of the array of data values, and is that important to your map?
- Is the scheme easily understood?
- Is it readily applied?
- Is the map legend easy to interpret?
- Is the scheme appropriate for the level of measurement?
- Is the data balanced, skewed, or has a peculiar distribution?
- Is it desirable to use descriptive statistics to inform the classification scheme?
- How many classes are useful?

The following guidelines can also help you create a useful classification scheme:

- classification should be meaningful, revealing, and impartial to the dataset (i.e. not presenting a biased view);
- the class interval should encompass the whole data range;
- class boundaries must not be overlapping;
- where possible, classes should not be empty (i.e. contain no data values);
- there should be enough classes to accurately portray the data, but not too many to dilute the data or produce an overly detailed display; and
- classes should be derived by some logical method understandable by the map reader.

Learning some of these guidelines is a good starting point to know when they can be broken. For instance, if you were making a propaganda map you might want to use a classification scheme that is inherently biased and use your understanding of the data distribution to convey that message.
1 data class

5 data classes

21 data classes (unclassed)

For 21 areas that represent 21 discrete data values, the choice of classes is between one and 21. Using one class simply classifies all data as the same. Using 21 classes (unclassed) gives each area a slightly different symbol from low to high. Using five data classes allows you to see which areas are similar in character. Symbol fills usually vary from light to dark to reflect the data array.

For qualitative data, different hues are normally used to show the different character of areas without implying any order of importance.
Digital elevation models

Elevation data supports numerous cartographic workflows for representing terrain.

A digital elevation model (DEM) represents the terrain surface created from elevation data, usually as a raster grid where each cell value is equal to the height at that position. A DEM is a fundamental data source used to create a wide range of terrain representations or portrayal of relief such as relief shading and hypsometric tinting. A DEM is a sample of elevations or depths at a specified resolution.

Although often used interchangeably, DEMs are not to be confused with a digital surface model (DSM) which represents Earth’s surface and all objects on it. Although most commonly a raster grid, some DEMs are in the form of a triangulated irregular network (TIN). DEM data is commonly sourced from remote sensing techniques and in addition to supporting relief portrayal is also important for city modelling and landscape visualization as well as many analytical applications.

The quality and resolution of a DEM is a function of the data acquisition. This is referenced as the absolute accuracy of each pixel in the raster grid as well as the relative accuracy of the morphology it represents. Many different factors affect these qualities such as terrain roughness, sampling density, grid resolution (pixel size), vertical resolution, and the various interpolation algorithms used.

Light detection and ranging (lidar) can also be used to develop surface data. Lidar measures distance by rapidly illuminating a target with laser light and records distance by measuring the time it takes to return to the measurement instrument. Lidar data is a popular dataset for creating a range of height-based datasets and provides more detailed resolutions of DEM, typically of 1 m or higher. Different return data, usually from airborne lidar sensors, can be used to create DEMs and DSMs from the high-resolution 3D point clouds that are created of the landscape.

Both government and private organizations create DEM data. As examples, GTOPO30 is available for the whole world at a resolution of 1 km but with variable quality. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on the Terra satellite provides 30 m resolution for 99% of the globe. A similar product is available for the United States under the Shuttle Radar Topography Mission (SRTM). Neither GTOPO30 nor SRTM cover the polar regions. The SRTM30Plus dataset combines GTOPO30, SRTM, and bathymetric data to create a global elevation model.

Many national mapping agencies also produce their own DEMs, which can often be at a higher resolution than global products. For instance, in the United States the USGS produces the National Elevation Dataset, which is a seamless DEM of the United States including Hawaii and Puerto Rico using 7.5’ arc second resolution.

DEM data alone is not particularly useful for cartographic representation. You can symbolise it to show where is higher and where is lower but that doesn’t make for a compelling map of terrain. The real value of a DEM is in using it to derive other representations. For instance, DEMs are the cornerstone to the calculation of contours, or the development of many different forms of hillshade. Because slope, gradient, and aspect can all be calculated between adjacent pixels, it is this post-processing and generation of alternative forms of terrain representation that are of significant value to cartography.

See also: Continuous surface maps | Planetary cartography | Point clouds | Slope, aspect, and gradient

Opposite: Digital elevation model of Mars and cartographic output.
Digital elevation models

Raw DEM of Valles Marineris, Mars with a black-white stretched colour ramp signifying low to high elevation values.

Derived cartographic product incorporating a hillshade, elevation tinting, and contours.

Derived 3D product incorporating a hillshade and elevation tint draped over an exaggerated surface model (x10)
Error and bias
All maps are authoritative and accurate, sometimes.

Maps are regarded as being definitive, accurate portrayals of information. That's the power they hold as people examine the lines, colours, wording, and symbology. They develop an impression of trust that is error-free, and this breeds confidence, sometimes over confidence in the efficacy of the product. All maps have errors, biases, and uncertainties. Many of these can be related to data accuracy and precision and the way in which these are either dealt with or propagated through the map. Other errors may exist. Biases may be introduced. These may often be unintentional.

Uncertainty can be a function of the data or the way it is represented. It is the degree to which the way something is mapped varies from its true value. This might be because of measurement errors, the processing and manipulation of the data, or the way in which the cartographer interprets and then represents the data. Error provides a way of measuring uncertainty in a map. For instance, we can quantify positional errors or determine the extent of attribute errors that might be missing or invalid. Errors may be unintentional, random, and difficult to spot though an understanding of potential error can provide a way to assess the extent to which a map can be trusted.

Bias is an extension of error and reflects a systematic distortion that is introduced into the map intentionally or otherwise. It can be introduced through misuse of data that results in a specific error being propagated across the map, affecting all similar features. It might also be added in more nefarious ways to influence the way in which a particular feature might be represented or a message framed.

Good editing helps to eliminate a large proportion of error. Checking sources, and checking and proofreading the final map remain vital tools. As with most creative works, it's easy to become so close to your own work that you find it difficult to see problems. Have other people look at your map and pass on comment. Often, an obvious error can be easily spotted by fresh eyes.

See also: Cognitive biases | Data accuracy and precision | Ethics | Integrity | Maps kill

Positionally, maps show location yet the precision of location affects the accuracy of the map. Generalised locations cannot be used for maps that are at a larger scale that the data collection scale supports. Positional accuracy also relates to the vertical aspect in the same way. Attribute measurements can also vary in accuracy and precision and similar thresholds of error tolerance defined.

Conceptual accuracy is more of a process than it is because of data. It reflects what is included or omitted, how it is represented, and whether the mediation of the cartographer has been objective. It reflects the level of knowledge the cartographer has about the subject and the mapping techniques used. Factual errors can exist, and sometimes the data may have inaccuracies that compromise the work. Data isn't always necessarily what it seems, and you may unintentionally pass such errors onto the map. Processing errors can often be introduced unintentionally through simply making a mistake. Being aware of the way in which data is processed can mitigate. For instance, simple rounding errors can cause havoc in statistical manipulation of data. Or geographies can become modified through over aggressive generalisation.

Opposite: Locals and Tourists (London) by Eric Fischer, 2010. The map claims to show 'incredible new detail', 'demographic, cultural, and social patterns down to city level'. The authors suggest it allows you to 'explore stories of space, language, and access to technology'. The data is derived from geotagged tweets. Blue for locals. Red for tourists. Yellow for either (unknown). Geotagged tweets account for around 1% of all tweets. Some 13% are imprecise. Only 87% of all internet users use social media. People who live in cities spend more time on social media. Only 16% of those who use social media use Twitter, and they are most likely to be adults aged 18-29, and male. The map has the appearance of detail and accuracy yet contains all the error, bias and uncertainty of the data.
Generalisation

Generalisation reduces, but clarifies, the information content of a map.

Generalisation is the overarching process of reducing the information content of a map because of changes in scale, map purpose, audience, or technical constraints. For instance, when preparing a small-scale map from high-resolution, large-scale data, some of the geographical features will likely need to be omitted or modified to retain clarity. All maps contain some form of generalisation since no map is a 1:1 representation of reality. Whatever your map project or data source, it’s almost guaranteed that performing generalisation will improve its appearance and use.

Generalisation can be performed objectively and subjectively. Algorithms are often used to simplify the sinuosity of lines from highly detailed versions to less detailed versions for representation at smaller scales. Beyond the use of algorithms, generalisation is partly a subjective process and relies on you to make judgements about how best to render geographical data at a different scale. In truth, generalisation is a mixture of the two processes. Appreciating how it can be applied and what choices work for different data at different scales goes a long way to making a map effective.

Generalisation is effectively a two-stage process with selection being a preprocessing step prior to the rest of the generalisation process. Selection involves the identification of features to retain or omit. In compiling a topographic map for a general-purpose audience, detailed base information such as the road layout, water features, urban areas, place-names, and elevation would be retained. For a thematic map at the same scale, many of these features are omitted because it is not deemed important in that context. Once decisions about what to retain or omit are made, processes that modify the graphical character of the mapped objects are usually performed. These processes can include simplification, classification, and symbolisation. Simplification eliminates unnecessary detail in a feature retained; classification categorises geographical data into summary form for map display; and symbolisation assigns graphical coding.

Generalisation used to be a cornerstone of map production. Working from surveyed data, cartographers would pore over every mapped feature and determine how best to represent it at a particular, usually derived, scale.

With the advent of modern mapping databases and the proliferation of open data, maps often display poor (or no) level of generalisation. The reasons for this are two-fold. Firstly, many mapmakers simply won’t have the knowledge or the tools to help them in the process. Secondly, generalising data is a time-consuming process, and the tendency in modern mapping is to simply publish the map.

The time it takes to perform generalisation is often overlooked in favour of timely map production. However, performing generalisation on detailed data for display at a smaller scale is always worth the effort. It is one of the key mechanisms to reducing clutter and making the map come to life.

Generalisation shouldn’t be performed to make the best use of map space. Geography is inherently heterogeneous and so you’ll always face decisions about what to include or omit. The ‘Baltimore’ phenomenon is a useful lesson in the pitfalls of generalisation. On many small-scale maps, Baltimore, Maryland, USA, is absent, yet smaller surrounding towns and cities with smaller populations are retained simply because of the availability of space for the map label. This has the potential to lead to problems when the map is read and the way in which towns and cities are perceived in relative terms. Making logical decisions is more important than simply using the availability of space as a determinant for generalisation.

See also: Scale and resolution | Schematic maps | Simplicity vs. complexity | Simplification | Symbolisation

Cartography.
Generalisation Wheel
A Cartographer’s Generalisation Palette
Map cube

How maps work and the functions they support can be represented as a map cube.

The map cube, originally developed as (cartography)³ by Alan MacEachren and D. R. Fraser Taylor in the early Nineties, shows how maps work. It’s an extremely useful way of considering how the purpose of your map is driven by other factors such as the amount of interaction required to read it, whether the map is for private study or public consumption, and whether you’re showing phenomena that are largely known and understood or whether you’re attempting to reveal new patterns and insight.

Thinking about your map in relation to the components of the map cube is a useful way to focus on the functions you need to support, and the form that the design needs to take.

Whether you are designing a printed map or a web map, considering who the map is for, the level of interaction you need, and whether the data is simply for presentation or query is key. These three aspects will go a long way toward shaping how you design the map itself.

For many web mapping applications, the map is now simply one component of a dashboard experience. Other components give the reader different opportunities. These might include tabular displays and rich interactive graphs as well as the functionality of interaction across the components. As a user selects from one component, information may update elsewhere. This sort of application might fall somewhere in the exploration or analysis realm in the map cube. Many data relations are previously unknown as the user searches for patterns. They might process their data and perform statistical analysis to discover new insights. The interaction between user and components and also among components is high, and this sort of work is likely done by individuals. Sharing results might require a different product, perhaps which falls more in the synthesis area.

Thinking inside the box of the map cube to conceptualise your product requirements is a useful way to ensure your maps work outside the box for their intended purpose.

See also: Defining map design | Form and function | Simplicity vs. complexity | Space-time cubes | Types of maps | Visualization wheel

Opposite: The Map Cube, after Alan MacEachren and D. R. Fraser Taylor, 1994
Communication
Low interactive graphics to present newly found spatial patterns to the public

Visualization
Highly interactive graphics to reveal unknown spatial patterns to an individual
A lavishly illustrated reference guide, Cartography by Kenneth Field is an inspiring and creative companion along the nonlinear journey toward designing a great map. This compendium for contemporary mapmaking distills the essence of cartography into easily digestible exercises, organized for convenience in finding the specific method or subject you need. Unlike books targeted toward deep scholarly discourse of cartographic theory, this book provides sound, visually compelling information that translates into practical ideas for modern mapmaking. At the intersection of science and art, Cartography serves as a guidepost for designing an accurate and effective map and makes a strong statement about the worth of cartography and cartographic thinking.

Dr. Kenneth Field brings a wealth of experience from academia and commercial practice into his book. He is a winner of numerous cartographic awards for his original maps as well as his writing. His work has been recognized by numerous peer-reviewed bodies for its quality, and his book brings together this body of cartographic knowledge for the first time.

"Read the book for pragmatic advice or to broaden your horizons. For me, it did both."
—Menno-Jan Kraak, president of the International Cartographic Association (ICA); professor, University of Twente, Enschede, The Netherlands; author of Mapping Time and coauthor of Cartography: Visualization of Geospatial Data

"An impressively creative and useful scholarly contribution."
—Mark Monmonier, author of How to Lie with Maps; Distinguished Professor of Geography, Syracuse University, New York

"What Kenneth Field has created here is a brilliant reference book on behalf of our field of cartography. Finally! A book that truly represents cartography in 2018."
—Christopher Wesson, The Bulletin of the Society of Cartographers

Kenneth Field