1 Cartography

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1.1 Introduction

Cartography is the science, technique and art of making and using maps. A good cartographer can not only have a good knowledge in science and technique but must also develop the skill in art when choosing types of lines, colour and text.

All maps are intended to be used for either navigation by foot, vehicles, or for describing spatial planning or for finding information in an atlas. Maps are very useful and never before have so many maps been distributed in many different information systems. The map is an efficient interface between a producer and a user, and by using GPS many things can be located on a map.

For a long time paper has been the most common material for maps. Nowadays, most maps are produced by using cartographic software and are distributed via Internet, but the cartographic rules are the same for all types of distribution. In this book we will describe how maps are produced and used, and how they are distributed, and how to get the needed data.

1.2 Different Types of Maps

The map deals with two fundamental elements: position and its attributes. Attributes may be occurrence, activity, incident, amount and changes over time. From the position and its attribute many relations may be described such as distance, dissemination, direction and variation, and combinations of different qualities such as income per person and level of education in different places. Different types of maps gives parts of this spectrum, and maps have the function to present these fact in a feasible manner. Maps have different scales, functions and contents and can be grouped as follows:

1. *Topographic maps* showing spatial relations between different geographical phenomena such as buildings, roads, boundaries and waters. Official topographic maps are produced by the National Mapping Organization (NMO). Most cities are also producing city plans. Topographic maps are also produced for special use in biking and canoeing. Many car navigation systems and services on Internet also provide topographic maps. Topographic maps are also used as background maps in property mapping and in maps for presenting the geographical aspects in spatial planning.
2. *Special maps* e.g. Sea Charts and maps for flying. These maps are for professional use and standardized by the UN. There are also specific sea charts for private use and special maps for orienteering, standardized by the International Orienteering Association (See Chapter 12). The Metro Map of London is also a special map.
3. *Thematic maps* contain descriptions of the geographical phenomena such as in geology (esp. soil and bedrock), and in land use and in vegetation. *Statistical maps* are also thematic maps. They show the geographical distribution of a statistical variable. See Chapter 7 Atlases for more information on statistical maps.

1.2.1 Thematic Maps

The weather map is the most common thematic map. Weather maps are presented every day on the TV for showing the present weather and for prediction of the weather. Weather maps can also be used for showing the movement of hurricanes and snowstorms, and in risk management for showing risks in flooding, draught and landslides. Weather maps are becoming more and more useful in showing the effects of the Climate Change, e.g. the melting of the polar ice. A lot more information can be found on the Internet.

Geological maps are thematic maps and very valid for finding minerals and oil, and the conditions of soil. They include rather complicated information and several geological map sheets are included in the result of doctoral studies in geology.

Atlases, however, have many types of thematic maps. The most common one is the choropleth map (choro for place and pleth for value) for showing the geographical distribution of a statistical variable in a given set of areas. As an example the population density per municipality can be shown in a choropleth map (See Chapter 7, Figures 7.11 -12). Start with making a table with the columns: municipality area identifier, the area, the size of the population, and perhaps also columns for the population divided in different sex and age groups. Open then a mapping or a geographic information system (GIS) software, where the boundaries for the municipalities should be given. The population density must also be given in different classes. It is important to have almost the same amount of objects in each class. Colour should be chosen to get a low intensity for low population density and darker intensity for a higher density. For a detailed information on colour choice see

Brewer (2005). It is also possible to use Google Earth for the construction of choropleth maps. The divisions into age groups can be used for construction of diagram maps and maps with pie charts (See Figure 1.1).

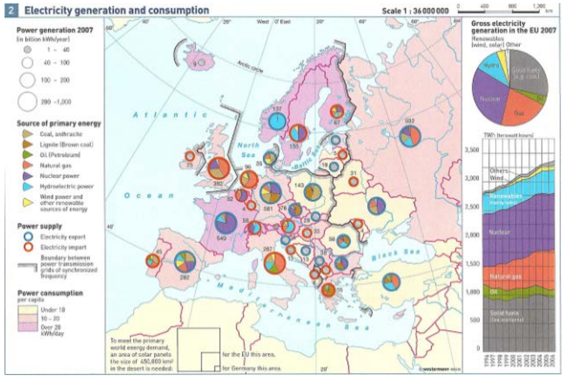

Figure 1.1 shows a thematic map with diagram and pie charts. © Diercke International Atlas (p. 48).

1.3 Cartographic Principles

1.3.1 Map Design

Maps like all other products must be designed before production. The design process is an iterative process and starts with a demand process telling the theme of the map and how it shall be used. The cartographer takes over and make a proposal that is tested on the criteria that have been given. When the demands are satisfied the map can be produced. The map design process is described in Figure 1.2. See also Chapter 4 and Anson and Ormeling (2002).

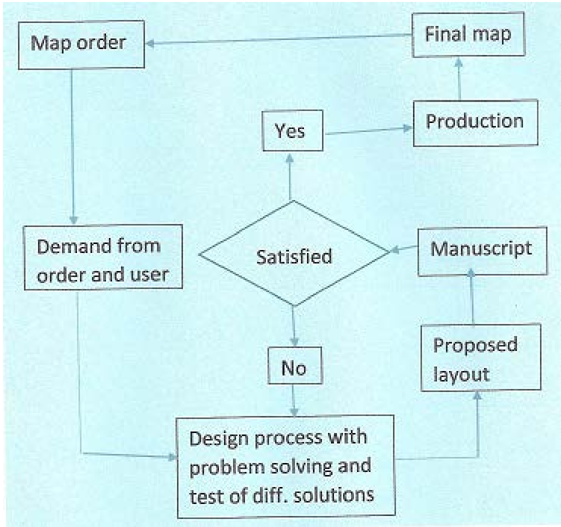

Figure 1.2. The design process starts with Map order. When the manuscript satisfies the demands it is time to go to production.

1.3.2 Symbolization

Symbolising means to use correct symbols in form and colour for the objects that will be represented. A map has different symbols and text. The symbols are used for describing some part of the reality, while the text is used for a more detailed description of the object that are depicted in the map.

Seen in a geometrical concept there are three types of symbols: *point symbols, line symbols and area symbols* (Examples of point, line and area symbols are given in the legends of e.g. topographic maps. In Figure 13.1, houses are shown as points, road as lines and land use as areas). The symbols may also vary in abstraction. The simplest symbols are the pure geometric ones. They represents their reality objects by showing their geometric and geographic attributes; a road is shown by lines and a lake by a polygon and so on. It is also possible to give more information. By giving the symbols different colours and different patterns it is possible to let area symbols represent different types of forest and let line symbols represent roads of different class (See Figure 13.1). Also more abstract symbols, e.g. figurative symbols or icons, may be used as point symbols. These symbols are very useful in city plans and tourist maps (Figure 1.3).

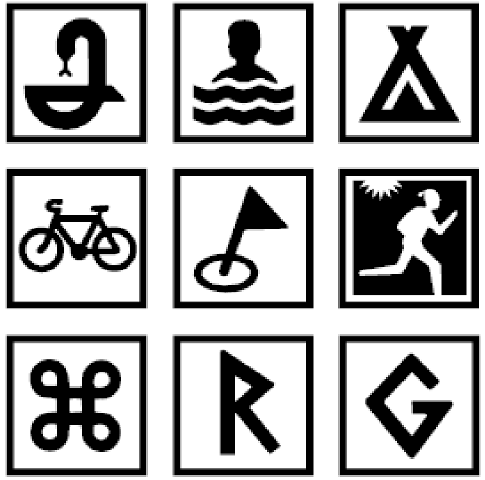

Figure 1.3 shows different icons for drug store, bathing place, camping site, road for biking, golf course, track for jogging with light, remarkable site, historical site and a geological site.

© Lantmäteriet Dnr R50160927_130001.

For more information on graphics and symbolization, it is possible to have a detailed study of Bertin´s Semiology of

Graphics (Bertin, 2011). The book is rather complex, but it is provides a good opportunity for someone who wants a full description of the graphic issues that cartography deals with.

1.3.3 Text

The text is an important part of the map and makes it easier for the user to understand the map. Typographical guidelines must be followed in order to achieve an understandable map. The typography includes dealing with fonts, size, colour and placement.

There are many fonts that can be used, but on the map their number should be limited to a few. The size should never be less than six points in order to be legible. Colour may be used to distinguish between different types of object, e.g. black for place names, blue for waters and green for nature objects. For a river the text should follow the line of the river. The name of an ocean may be curved to indicate that the area of the ocean is big. The placement should also indicate where the object is located. The name of a city should be placed upon land and the name of a lake should be placed in the lake. More information about typography is given in Chapter 13 Printing Maps.

1.4 Visual Hierarchy and Communication

1.4.1 Visual Hierarchy

When studying a map we found different information layers and that one layer is more visual forming the foreground of the map. The background of the map gives the location and orientation to other objects of the map. A topographic map for car driving has the roads in the foreground. In atlases that is more obvious. The theme of the map is in the foreground and the topography is in the background mostly for orientation.

The best way to handle visual hierarchy is to use colour. More intense colours are used for the foreground that is the theme of the map, and less intense colours for the background. In a map for car navigation the roads would be depicted with stronger colour. Also icons may be used to strengthen the foreground. City plans for visitors have icons to make things such as hotels and restaurants more obvious.

1.4.2 Communication

In many communication processes maps as well as text, diagrams and images are important tools for giving a user important information about geographical aspects of the realty. There are, however, many realities. A topographic map represents the physical landscape, a geological map represents the geological landscape, and a demographic map the demographic landscape. The map is a model of the reality as the cartographer understand it. The cartographer uses a cartographic language to produce the map to be read by a map user. Here we see a problem. The map user may not have the same view of the reality. In Figure 1.4 we see that the realities as seen by the cartographer and as seen by the user of the map are different.

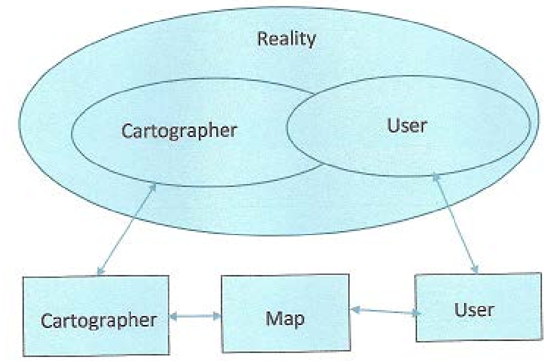

Figure 1.4 shows a model of the communication process and that there are a different view of the reality between the user and the cartographer.

1.5 Scale and Projection

1.5.1 Scale

A map may be seen as a description of the real world into a symbolical form but also in a geometrical form. The chosen scale of the map is a compromise between the amount of object that will be given and the view that will be given in order to give an understandable geographical context. Scale indicates the ratio between the length of a given distance in reality and the length of that distance as represented on the map. If a distance of 8 kilometres is rendered on the map by a length of a line of 4 cm, the scale of that map is 4cm/8km or 4cm/800,000cm = 1:200,000

On a map with a larger scale, such as 1:50,000, that line would be longer 16cm) and on a map with a smaller scale (such as 1:1,000,000), that length would be smaller (0.8cm). It is also obvious that a small scale map (which has less space on the paper or screen for the same area) is more generalised than a large scale map. A meandering river may not be shown in detail in a small scale map. It is the same with shorelines. When measuring the length of a shoreline in a map, the scale must be given. In the real world, the length of a shoreline is unlimited. For any length given it is possible to get a longer length by being more detailed.

Automatic generalisation is difficult, but it is introduced more and more. In some countries, e.g. United States of America, large scale topographic maps are generalised stepwise into smaller and smaller scales.

1.5.2 Projection

The Earth is almost a sphere and it is not possible to represent the image of this spherical Earth on a flat paper or screen without distorting it. The systematic way of rendering it two-dimensionally is called a projection. Mercator projection (See Figure 1.5), with Europe and Africa in the middle distorts, as areas with longer distance from the equator are progressively exaggerated. From a map in this projection, it is easy to understand why America is called the West and Japan the Far East. The concept of Western and Eastern countries cannot be understood in any other way.

Projections, fully described in Chapter 9, may be classified into cylindrical, conic and azimuthal ones. Here only the cylindrical one will be described. In that projection the Earth is put into a cylinder with the equator brushing the cylinder. When we project each point on the Earth surface from the centre of the Earth on the cylinder, this projection is called the Mercator projection. If a meridian brushes the cylinder however, we get a transverse Mercator projection. The transverse Mercator projection is often chosen for national topographic maps. For large countries many such projections must be used with different meridians chosen. There is now a standard, Universal Transverse Mercator (UTM), with 60 zones around the Earth giving each zone a band of 6 degrees in longitude.

A Mercator projection with the equator as reference results in exaggerated areas in the higher latitudes, and the poles even become straight lines. Hence, that projection is not an equal area one. But, on the other hand, it is conformal: angles measured on the map are the same as measured on the Earth. If a compass direction is taken e.g. over the Atlantic from Norway to Rio de Janerio and the compass direction is always followed, the goal will be reached. However, that route is not the shortest one. The shortest line forms a bow as can be seen in Figure 15.13.

The original Mercator projection is not so usable in practice. But if you are very British you may want to see an area-exaggerated image of the Commonwealth, as Canada and Australia are partly located in higher latitudes. For Atlases an equal area projection is wanted such as the Mollweide´s projection (See Figure 1.5).

When mapping it is important to know the location in both latitude and longitude both on Land and Sea. The latitude has for a long time been found by reference to the stars, the Polar star in the Northern hemisphere and the Southern Cross in the Southern hemisphere. The longitude is more difficult to find without a correct time. In mapping, old maps frequently have the wrong distance in a West East direction as compared to the more correct distance in a North South direction. In sailing, many ships were wrecked because the navigator could not measure the longitude in a correct way. With the use of modern technology such incorrect measurements of latitudes are avoided. A GPS give both location and a correct time.

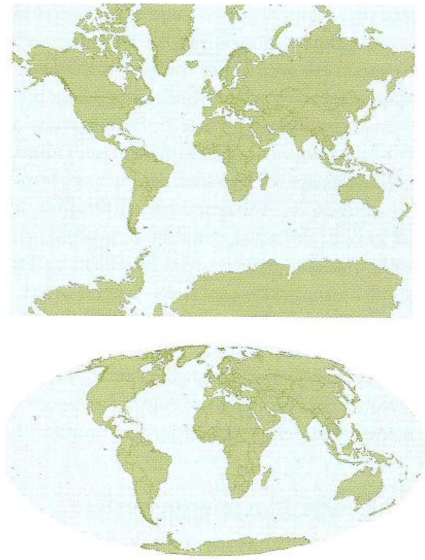

Figure 1.5 shows the World in two different projections. Above is Mercator´s conformal projection (angle correct) and below is Mollweide´s projection (equal area). Source: Esri.

The next phase in mapping is to determine a coordinate system, where longitudes and latitudes measured on the Earth can be transformed to planar coordinates for drawing the Earth or part of it in two dimensions such as on a paper sheet. That is a rather complicated problem and many decisions must be taken regarding the shape of the Earth in order to get a good mathematical solution. Nowadays, we have a solution called the World

Geodetic System, established in 1984 (WGS84). This system is also used in Global Navigation Satellite Systems, of which GPS is the best known one. In order to use the map in navigation the reference frame must be noted on the map in the form of longitudes and latitudes measured in accordance with WGS84.

Land surveyors use the geodetic network to determine positions of points in their measurements. When a new land parcel is going to be created, accurate positions for all corners must be found and their location should be given in the coordinate system. References must also be given so the location of that point can be recalculated.

More information on projections and coordinate systems can be found in Chapter 9 Map Projections and Reference Systems.

1.6 Different Map Media

The oldest maps were made on clay plates and found in Babylon. Maps have also been found graved in stones along the Silk Road to show where the camels of the caravans could get water. In Jordan there are maps in mosaic. Early maps have also been produced on papyrus and rice paper. In a museum in Olomouc, Check Republic, there is a map written on a Mammoth task supposed to be a hunting map. If that is a map it is the oldest map found dated to 25,000 BC.

However, for a long time ordinary paper has been one of the most common map media. But now, the screens on computers and mobiles are the most common ones and the web is the most popular platform for communicating information in map form.

1.7 Historical Maps

1.7.1 Antiquity

The first known cartographer was Klaudios Ptolemaios, a Greek who lived in Alexandria, Egypt. He died about AD 165 and he knew that the Earth was round, a fact that later on was denied by the Church. He was a scientist in astronomy, geography, and mathematics. In geography, his most important work was the Geographia, a manual that showed what the Romans knew about the world in his time, combined with a guide how to produce world and regional maps (see figure 1.6), for which he collected the coordinates of some 8000 towns and other geographical objects. Figure 1.7 shows an 11th century manuscript of his Geographia, in the original Greek, preserved in the Vatopedi monastery on Mount Athos in Greece.

Figure 1.6. Ptolemaios´s world map. In the centre, the Arabian peninsula and the Nile are depicted.
Source: Wikipedia.

Figure 1.7 shows Ferjan Ormeling studying the Geographia at Mount Athos, Greece, in *May 2006.*
Photo: Bengt Rystedt.

Figure 1.8 shows a road map with the military roads used for transportation of soldiers and distribution of messages in the Roman Empire. A series of forts and stations were spread out along the major road systems connecting the regions of the Roman world. The relay points provided horses to dispatch riders for a post service. The distances between the points are also indicated. The map is believed to have been created during the fifth century. The map was forgotten and discovered in a library in Worms and then handed over to Konrad Peutinger in 1508, after whom the map is now called. The map is now conserved at the National Library in Vienna, Austria.

Note that the Mediterranean looks like a river, so the scale in the North–South is smaller than in West–East.

The whole map can be seen at http://upload.wikimedia.org/wikipedia/commons/5/50/TabulaPeutingeriana.jpg.

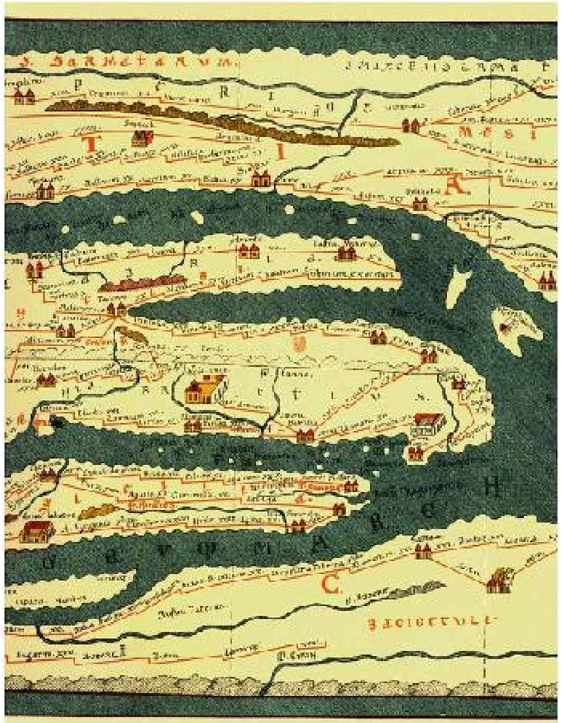

Figure 1.8 shows a part of the Peutinger map. The height of the original map is 0.34 meters, the length is 6.75 meters and it covers the area from Portugal to India.
Source: http://en.wikipedia.org/wiki/Tabula_Peutingeriana.

In roughly the same period in China, under the Han dynasty, scientist Zheng Hang developed a grid system on which he mapped his country.

1.7.2 The Medieval Time

Arabian scholars followed the antique knowledge and took care of the work of Ptolemaios, but the theologians of the Christian church tried for incorporation of cartography into a religious frame. During the period 300 to 1100 AD, cartography declined in Western countries.

However, some maps have been produced and several maps are covering the known antique world. A diagram with the letter T in an O, equal to the surrounding ocean, was constructed (see Figure 1.9). If the island Delos earlier had been the centre of the world, it was now Jerusalem.

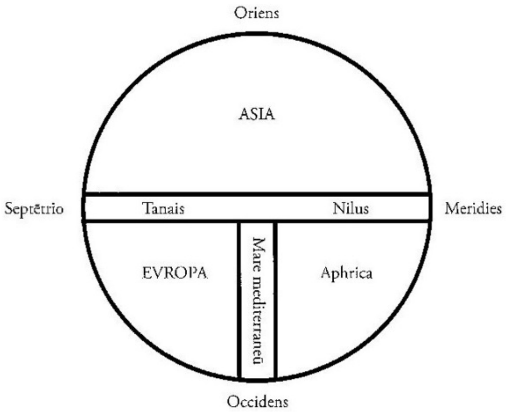

Figure 1.9 A diagram showing a medieval T-O-map oriented towards the East. The horizontal line is the Don and Nile rivers. The vertical line is the Mediterranean. O represents the surrounding ocean.
Source: Ehrensvärd (2006, pp. 26).

Independent from these religious T - O maps, in the 13th century mariners from Italian ports developed highly accurate charts of the Mediterranean, called portolan charts (see figure 1.10). At this moment it is not known from where they derived their knowledge and techniques (Nicolai, 2014).

Figure 1.10 The portolan chart by Diogo Homem (1561).
Source ICA, 1995, pp. 93.

1.7.3 Renaissance and beyond

In the first half of the 16th century land surveying techniques were developed that enabled surveyors to accurately survey towns, provinces and countries. During the Age of Discovery Europeans were able to establish direct contact with inhabitants of other continents and map their territories, with the help of celestial navigation techniques.. Similtaneously, of an increasing number of towns outside Europe the coordinates were measured enabling cartographers to produce more and more detailed and accurate maps. In the beginning of the Age of Discovery it were the Portuguese, Spanish and Italian cartographers that produced manuscript maps of the new doscoveries. From the second half of the 16th century cartographic publishing houses developed in Flanders and Amsterdam, where Ortelius and Blaeu published lavishly decorated European and world atlases, consisting of small-scale overview maps..

Simultaneously, large-scale property or cadastral mapping also flourished, its results can be found in different archives. The most detailed ones are the property or cadastral maps that can be found in Survey Archives. A paper by Rystedt (2006) shows how the Survey Archive of Sweden has been used to give an overview of the development of property mapping in a village of Sweden. These detailed maps are also of great interest when earlier generations are looked for. The early emigrants, to e.g. the USA, have many descendants that want to find out their forefathers relatives and where these lived. The property maps were called geometric maps and were used to construct geographic maps at a smaller scale. Maps of early defence constructions are also common and can be used for the same purpose.

City Plans can be found in City Archives; they show how cities have been rebuilt at different times, giving a good understanding of the development of the municipality.

1.7.4 Well-known Cartographers

Zhang Heng (AD 78-139) was a Chinese cartographer, living during the Han dynasty, to whom the establishment of the Chinese grid system in cartography is attributed. See: http://en.wikipedia.org/wiki/Zhang_Heng

Abraham Ortelius (1527 –1598) was a Flemish cartographer and geographer, generally recognized as the creator of the first modern atlas, the *Theatrum Orbis Terrarum* (Theatre of the World). He is also believed to be the first person to imagine that the continents were joined together before drifting to their present positions. See: http://en.wikipedia.org/wiki/Abraham_Ortelius.

Joan Blaeu (1596-1673), a Dutch cartographer, not only produced maps, but he also collected maps, which he redrew and printed in his company. (http://en.wikipedia.org/wiki/Joan_Blaeu).

Another European is Johann Babtist Homann (1664-1724), a German geographer and cartographer. He produced many maps, but also collected maps, which he redrew and published together with his own maps in his own publishing house, (http://en.wikipedia.org/wiki/Johann_Homann).

Ino Tadataka (1745-1818) was a Japanese surveyor and cartographer, the first to produce a complete map of Japan using modern surveying techniques. See: http://en.wikipedia.org/wiki/In%C5%8D_Tadataka

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