



EIILM UNIVERSITY
S I K K I M

CARTOGRAPHY

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Chapter 1

Cartography

Cartography is the study and practice of making maps. Combining science, aesthetics, and technique, cartography builds on the premise that reality can be modeled in ways that communicate spatial information effectively.

The fundamental problems of traditional cartography are to:

- Set the map's agenda and select traits of the object to be mapped. This is the concern of map editing. Traits may be physical, such as roads or land masses, or may be abstract, such as toponyms or political boundaries.
- Represent the terrain of the mapped object on flat media. This is the concern of map projections.
- Eliminate characteristics of the mapped object that are not relevant to the map's purpose. This is the concern of generalization.
- Reduce the complexity of the characteristics that will be mapped. This is also the concern of generalization.
- Orchestrate the elements of the map to best convey its message to its audience. This is the concern of map design.

Modern cartography is largely integrated with geographic information science (GIScience) and constitutes many theoretical and practical foundations of geographic information systems.

The earliest known map is a matter of some debate, both because the definition of "map" is not sharp and because some artifacts speculated to be maps might actually be something else. A wall painting, which may depict the ancient Anatolian city of Çatalhöyük (previously known as Catal Huyuk or Çatal Hüyük), has been dated to the late 7th millennium BCE. Other known maps of the ancient world include the Minoan "House of the Admiral" wall painting from c. 1600 BCE,

showing a seaside community in an oblique perspective and an engraved map of the holy Babylonian city of Nippur, from the Kassite period (14th – 12th centuries BCE). The oldest surviving world maps are the Babylonian world maps from the 9th century BCE. One shows Babylon on the Euphrates, surrounded by a circular landmass showing Assyria, Urartu and several cities, in turn surrounded by a "bitter river" (Oceanus), with seven islands arranged around it. Another depicts Babylon as being further north from the center of the world.

The ancient Greeks and Romans created maps, beginning at latest with Anaximander in the 6th century B. In the 2nd century AD, Ptolemy produced his treatise on cartography, *Geographia*. This contained Ptolemy's world map - the world then known to Western society (Ecumene). As early as the 8th century, Arab scholars were translating the works of the Greek geographers into Arabic.

In ancient China, geographical literature spans back to the 5th century BC. The oldest extant Chinese maps come from the State of Qin, dated back to the 4th century BC, during the Warring States period. In the book of the *Xin Yi Xiang Fa Yao*, published in 1092 by the Chinese scientist Su Song, a star map on the equidistant cylindrical projection. Although this method of charting seems to have existed in China even prior to this publication and scientist, the greatest significance of the star maps by Su Song is that they represent the oldest existent star maps in printed form.

Early forms of cartography of India included the locations of the Pole star and other constellations of use. These charts may have been in use by the beginning of the Common Era for purposes of navigation.

Mappa mundi are the Medieval European maps of the world. Approximately 1,100 mappae mundi are known to have survived from the Middle Ages. Of these, some 900 are found illustrating manuscripts and the remainder exist as stand-alone documents.



The Tabula Rogeriana, drawn by Muhammad al-Idrisi for Roger II of Sicily in 1154

The Arab geographer Muhammad al-Idrisi produced his medieval atlas Tabula Rogeriana in 1154. He incorporated the knowledge of Africa, the Indian Ocean and the Far East, gathered by Arab merchants and explorers with the information inherited from the classical geographers to create the most accurate map of the world up until his time. It remained the most accurate world map for the next three centuries.



Europa regina in Sebastian Münster's "Cosmographia", 1570

In the Age of Exploration, from the 15th century to the 17th century, European cartographers both copied earlier maps (some of which had been passed down for centuries) and drew their own based on explorers' observations and new surveying techniques. The invention of the magnetic compass, telescope and sextant enabled increasing accuracy. In 1492, Martin Behaim, a German cartographer, made the oldest extant globe of the Earth.

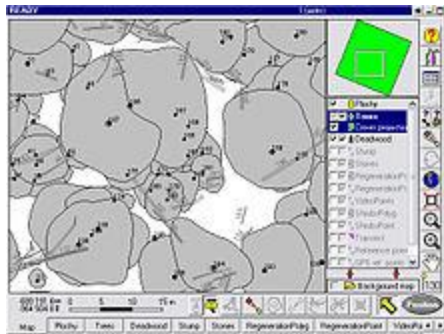
Johannes Werner refined and promoted the Werner projection. In 1507, Martin Waldseemüller produced a globular world map and a large 12-panel world wall map (*Universalis Cosmographia*) bearing the first use of the name "America". Portuguese cartographer Diego Ribero was the author of the first known planisphere with a graduated Equator (1527). Italian cartographer Battista Agnese produced at least 71 manuscript atlases of sea charts.

Due to the sheer physical difficulties inherent in cartography, map-makers frequently lifted material from earlier works without giving credit to the original cartographer. For example, one of the most famous early maps of North America is unofficially known as the "Beaver Map", published in 1715 by Herman Moll. This map is an exact reproduction of a 1698 work by Nicolas de Fer. De Fer in turn had copied images that were first printed in books by Louis Hennepin, published in 1697, and François Du Creux, in 1664. By the 18th century, map-makers started to give credit to the original engraver by printing the phrase "After [the original cartographer]" on the work.

Technological changes



A pre-Mercator nautical chart of 1571, from Portuguese cartographer Fernão Vaz Dourado (c. 1520–c. 1580). It belongs to the so-called plane chart model, where observed latitudes and magnetic directions are plotted directly into the plane, with a constant scale, as if the Earth were a plane (Portuguese National Archives of Torre do Tombo, Lisbon).



Mapping can be done with GPS and laser rangefinder directly in the field (for example by Field-Map technology). Real-time map construction improves productivity and quality of mapping. Image shows mapping of forest structure (position of trees, dead wood and canopy).

In cartography, technology has continually changed in order to meet the demands of new generations of mapmakers and map users. The first maps were manually constructed with brushes and parchment; therefore, varied in quality and were limited in distribution. The advent of magnetic devices, such as the compass and much later, magnetic storage devices, allowed for the creation of far more accurate maps and the ability to store and manipulate them digitally.

Advances in mechanical devices such as the printing press, quadrant and vernier, allowed for the mass production of maps and the ability to make accurate reproductions from more accurate data. Optical technology, such as the telescope, sextant and other devices that use telescopes, allowed for accurate surveying of land and the ability of mapmakers and navigators to find their latitude by measuring angles to the North Star at night or the sun at noon.

Advances in photochemical technology, such as the lithographic and photochemical processes, have allowed for the creation of maps that have fine details, do not distort in shape and resist moisture and wear. This also eliminated the need for engraving, which further shortened the time it takes to make and reproduce maps.

Advancements in electronic technology in the 20th century ushered in another revolution in cartography. Ready availability of computers and peripherals such as monitors, plotters, printers, scanners (remote and document) and analytic stereo plotters, along with computer programs for visualization, image processing, spatial analysis, and database management, have democratized

and greatly expanded the making of maps. The ability to superimpose spatially located variables onto existing maps created new uses for maps and new industries to explore and exploit these potentials. See also: digital raster graphic.

These days most commercial-quality maps are made using software that falls into one of three main types: CAD, GIS and specialized illustration software. Spatial information can be stored in a database, from which it can be extracted on demand. These tools lead to increasingly dynamic, interactive maps that can be manipulated digitally.

With the field rugged computers, GPS and laser rangefinders, it is possible to perform mapping directly in the terrain. Construction of a map in real time, for example by using Field-Map technology, improves productivity and quality of the result.

General vs thematic cartography



Small section of an orienteering map.



Topographic map of Easter Island.



Relief map Sierra Nevada

In understanding basic maps, the field of cartography can be divided into two general categories: general cartography and thematic cartography. General cartography involves those maps that are constructed for a general audience and thus contain a variety of features. General maps exhibit many reference and location systems and often are produced in a series. For example, the 1:24,000 scale topographic maps of the United States Geological Survey (USGS) are a standard as compared to the 1:50,000 scale Canadian maps. The government of the UK produces the classic 1:50,000 (replacing the older 1 inch to 1 mile) "Ordnance Survey" maps of the entire UK and with a range of correlated larger- and smaller-scale maps of great detail.

Thematic cartography involves maps of specific geographic themes, oriented toward specific audiences. A couple of examples might be a dot map showing corn production in Indiana or a shaded area map of Ohio counties, divided into numerical choropleth classes. As the volume of geographic data has exploded over the last century, thematic cartography has become increasingly useful and necessary to interpret spatial, cultural and social data.

An orienteering map combines both general and thematic cartography, designed for a very specific user community. The most prominent thematic element is shading, that indicates degrees of difficulty of travel due to vegetation. The vegetation itself is not identified, merely classified by the difficulty ("fight") that it presents.

A topographic map is primarily concerned with the topographic description of a place, including (especially in the 20th and 21st centuries) the use of contour lines showing elevation. Terrain or relief can be shown in a variety of ways (see Cartographic relief depiction).

A topological map is a very general type of map, the kind you might sketch on a napkin. It often disregards scale and detail in the interest of clarity of communicating specific route or relational information. Beck's London Underground map is an iconic example. Though the most widely used map of "The Tube," it preserves little of reality: it varies scale constantly and abruptly, it straightens curved tracks, and it contorts directions. The only topography on it is the River Thames, letting the reader know whether a station is north or south of the river. That and the topology of station order and interchanges between train lines are all that is left of the geographic space. Yet those are all a typical passenger wishes to know, so the map fulfils its purpose.

Map purpose and selection of information

Arthur H. Robinson, an American cartographer influential in thematic cartography, stated that a map not properly designed "will be a cartographic failure." He also claimed, when considering all aspects of cartography, that "map design is perhaps the most complex." [19] Robinson codified the mapmaker's understanding that a map must be designed foremost with consideration to the audience and its needs.

From the very beginning of mapmaking, maps "have been made for some particular purpose or set of purposes". The intent of the map should be illustrated in a manner in which the percipient acknowledges its purpose in a timely fashion. The term percipient refers to the person receiving information and was coined by Robinson. The principle of figure-ground refers to this notion of engaging the user by presenting a clear presentation, leaving no confusion concerning the purpose of the map. This will enhance the user's experience and keep his attention. If the user is unable to identify what is being demonstrated in a reasonable fashion, the map may be regarded as useless.

Making a meaningful map is the ultimate goal. Alan MacEachren explains that a well designed map "is convincing because it implies authenticity" (1994, pp. 9). An interesting map will no doubt engage a reader. Information richness or a map that is multivariate shows relationships within the map. Showing several variables allows comparison, which adds to the meaningfulness of the map. This also generates hypothesis and stimulates ideas and perhaps further research. In order to convey the message of the map, the creator must design it in a manner which will aid the

reader in the overall understanding of its purpose. The title of a map may provide the "needed link" necessary for communicating that message, but the overall design of the map fosters the manner in which the reader interprets it (Monmonier, 1993, pp. 93).

In the 21st century it is possible to find a map of virtually anything from the inner workings of the human body to the virtual worlds of cyberspace. Therefore there are now a huge variety of different styles and types of map - for example, one area which has evolved a specific and recognisable variation are those used by public transport organisations to guide passengers, namely urban rail and metro maps, many of which are loosely based on 45 degree angles as originally perfected by Harry Beck and George Dow.

Naming conventions

Most maps use text to label places and for such things as the map title, legend and other information. Although maps are often made in one specific language, place names often differ between languages. So a map made in English may use the name Germany for that country, while a German map would use Deutschland and a French map Allemagne. A non-native term for a place is referred to as an exonym.

In some cases the correct name is not clear. For example, the nation of Burma officially changed its name to Myanmar, but many nations do not recognize the ruling junta and continue to use Burma. Sometimes an official name change is resisted in other languages and the older name may remain in common use. Examples include the use of Saigon for Ho Chi Minh City, Bangkok for Krung Thep and Ivory Coast for Côte d'Ivoire.

Difficulties arise when transliteration or transcription between writing systems is required. Some well-known places have well-established names in other languages and writing systems, such as Russia or Rußland for Росси́я, but in other cases a system of transliteration or transcription is required. Even in the former case, the exclusive use of an exonym may be unhelpful for the map user. It will not be much use for an English user of a map of Italy to show Livorno only as "Leghorn" when road signs and railway timetables show it as "Livorno". In transliteration, the characters in one script are represented by characters in another. For example, the Cyrillic letter P is usually written as R in the Latin script, although in many cases it is not as simple as a one-

for-one equivalence. Systems exist for transliteration of Arabic, but the results may vary. For example, the Yemeni city of Mocha is written variously in English as Mocha, Al Mukha, al-Mukhā, Mocca and Moka. Transliteration systems are based on relating written symbols to one another, while transcription is the attempt to spell in one language the phonetic sounds of another. Chinese writing is now usually converted to the Latin alphabet through the Pinyin phonetic transcription systems. Other systems were used in the past, such as Wade-Giles, resulting in the city being spelled Beijing on newer English maps and Peking on older ones.

Further difficulties arise when countries, especially former colonies, do not have a strong national geographic naming standard. In such cases, cartographers may have to choose between various phonetic spellings of local names versus older imposed, sometimes resented, colonial names. Some countries have multiple official languages, resulting in multiple official placenames. For example, the capital of Belgium is both Brussel and Bruxelles. In Canada, English and French are official languages and places have names in both languages. British Columbia is also officially named la Colombie-Britannique. English maps rarely show the French names outside of Quebec, which itself is spelled Québec in French.

The study of placenames is called toponymy, while that of the origin and historical usage of placenames as words is etymology.

In order to improve legibility or to aid the illiterate, some maps have been produced using pictograms to represent places. The iconic example of this practice is Lance Wyman's early plans for the Mexico City Metro, on which stations were shown simply as stylized logos. Wyman also prototyped such a map for the Washington Metro, though ultimately the idea was rejected. Other cities experimenting with such maps are Fukuoka, Guadalajara and Monterrey.

Map symbology



A map of the southwest coast of Ireland created in the early 18th century. Notice the north arrow at the bottom of the map. Also, colors are used in the map to distinguish different geographical areas.

The quality of a map's design affects its reader's ability to extract information and to learn from the map. Cartographic symbology has been developed in an effort to portray the world accurately and effectively convey information to the map reader. A legend explains the pictorial language of the map, known as its symbology. The title indicates the region the map portrays; the map image portrays the region and so on. Although every map element serves some purpose, convention only dictates inclusion of some elements, while others are considered optional. A menu of map elements includes the neatline (border), compass rose or north arrow, overview map, bar scale, map projection and information about the map sources, accuracy and publication.

When examining a landscape, scale can be intuited from trees, houses and cars. Not so with a map. Even such a simple thing as a north arrow is crucial. It may seem obvious that the top of a map should point north, but this might not be the case.

Map coloring is also very important. How the cartographer displays the data in different hues can greatly affect the understanding or feel of the map. Different intensities of hue portray different objectives the cartographer is attempting to get across to the audience. Today, personal computers can display up to 16 million distinct colors at a time. This fact allows for a multitude of color options for even for the most demanding maps. Moreover, computers can easily hatch patterns in colors to give even more options. This is very beneficial, when symbolizing data in categories such as quintile and equal interval classifications.

Quantitative symbols give a visual measure of the relative size/importance/number that a symbol represents and to symbolize this data on a map, there are two major classes of symbols used for portraying quantitative properties. Proportional symbols change their visual weight according to a quantitative property. These are appropriate for extensive statistics. Choropleth maps portray data collection areas, such as counties or census tracts, with color. Using color this way, the darkness and intensity (or value) of the color is evaluated by the eye as a measure of intensity or concentration.

Map generalization

A good map has to compromise between portraying the items of interest (or themes) in the right place on the map, and the need to show that item using text or a symbol, which take up space on the map and might displace some other item of information. The cartographer is thus constantly making judgements about what to include, what to leave out and what to show in a slightly incorrect place. This issue assumes more importance as the scale of the map gets smaller (i.e. the map shows a larger area) because the information shown on the map takes up more space on the ground. A good example from the late 1980s was the Ordnance Survey's first digital maps, where the absolute positions of major roads were sometimes a scale distance of hundreds of metres away from ground truth, when shown on digital maps at scales of 1:250,000 and 1:625,000, because of the overriding need to annotate the features.

Map projections

The Earth being spherical, any flat representation generates distortions such that shapes and areas cannot both be conserved simultaneously, and distances can never all be preserved.[24] The mapmaker must choose a suitable **map projection** according to the space to be mapped and the purpose of the map.

CARTOGRAPHIC ERRORS

Some maps contain deliberate errors or distortions, either as propaganda or as a "watermark" to help the copyright owner identify infringement if the error appears in competitors' maps. The

latter often come in the form of nonexistent, misnamed, or misspelled "trap streets". Other names and forms for this are paper townsites, fictitious entries, and copyright easter eggs.

Another motive for deliberate errors is cartographic "vandalism": a mapmaker wishing to leave his or her mark on the work. Mount Richard, for example, was a fictitious peak on the Rocky Mountains' continental divide that appeared on a Boulder County, Colorado map in the early 1970s. It is believed to be the work of draftsman Richard Ciacci. The fiction was not discovered until two years later.

Sandy Island (New Caledonia) is an example of a fictitious location that stubbornly survives, reappearing on new maps copied from older maps while being deleted from other new editions. The time and reason for its original placement on maps is unknown.

Chapter 2

History of Cartography

Cartography , or mapmaking, has been an integral part of the human history for a long time, possibly up to 8,000 years. From cave paintings to ancient maps of Babylon, Greece, and Asia, through the Age of Exploration, and on into the 21st century, people have created and used maps as essential tools to help them define, explain, and navigate their way through the world. Maps began as two-dimensional drawings but can also adopt three-dimensional shapes (globes, models) and be stored in purely numerical forms.

EARLIEST KNOWN MAPS

The earliest known maps are of the heavens, not the earth. Dots dating to 16,500 BC found on the walls of the Lascaux caves map out part of the night sky, including the three bright stars Vega, Deneb, and Altair (the Summer Triangle asterism), as well as the Pleiades star cluster. The Cuevas de El Castillo in Spain contain a dot map of the Corona Borealis constellation dating from 12,000 BC.

Cave painting and rock carvings used simple visual elements that may have aided in recognizing landscape features, such as hills or dwellings. A map-like representation of a mountain, river, valleys and routes around Pavlov in the Czech Republic has been dated to 25,000 BP, and a 14,000 BP polished chunk of sandstone from a cave in Spanish Navarre may represent similar features superimposed on animal etchings, although it may also represent a spiritual landscape, or simple incisions.

Another ancient picture that resembles a map was created in the late 7th millennium BC in Çatalhöyük, Anatolia, modern Turkey. This wall painting may represent a plan of this Neolithic village; however, recent scholarship has questioned the identification of this painting as a map.

Whoever visualized the Çatalhöyük "mental map" may have been encouraged by the fact that houses in Çatalhöyük were clustered together and were entered via flat roofs. Therefore, it was normal for the inhabitants to view their city from a bird's eye view. Later civilizations followed

the same convention; today, almost all maps are drawn as if we are looking down from the sky instead of from a horizontal or oblique perspective. The logical advantage of such a perspective is that it provides a view of a greater area, conceptually. There are exceptions: one of the "quasi-maps" of the Minoan civilization on Crete, the "House of the Admiral" wall painting, dating from c. 1600 BC, shows a seaside community in an oblique perspective.

ANCIENT NEAR EAST

Maps in Ancient Babylonia were made by using accurate surveying techniques.

For example, a 7.6×6.8 cm clay tablet found in 1930 at Ga-Sur, near contemporary Kirkuk, shows a map of a river valley between two hills. Cuneiform inscriptions label the features on the map, including a plot of land described as 354 iku (12 hectares) that was owned by a person called Azala. Most scholars date the tablet to the 25th to 24th century BC; Leo Bagrow dissents with a date of 7000 BC.[page needed] Hills are shown by overlapping semicircles, rivers by lines, and cities by circles. The map also is marked to show the cardinal directions.

An engraved map from the Kassite period (14th–12th centuries BC) of Babylonian history shows walls and buildings in the holy city of Nippur.

In contrast, the Babylonian World Map, the earliest surviving map of the world (c. 600 BC), is a symbolic, not a literal representation. It deliberately omits peoples such as the Persians and Egyptians, who were well known to the Babylonians. The area shown is depicted as a circular shape surrounded by water, which fits the religious image of the world in which the Babylonians believed.

Examples of maps from ancient Egypt are quite rare. However, those that have survived show an emphasis on geometry and well-developed surveying techniques, perhaps stimulated by the need to re-establish the exact boundaries of properties after the annual Nile floods. The Turin Papyrus Map, dated c. 1160 BC, shows the mountains east of the Nile where gold and silver were mined, along with the location of the miners' shelters, wells, and the road network that linked the region with the mainland. Its originality can be seen in the map's inscriptions, its precise orientation, and the use of colour.

EARLY GREEK LITERATURE

In reviewing the literature of early geography and early conceptions of the earth, all sources lead to Homer, who is considered by many (Strabo, Kish, and Dilke) as the founding father of Geography. Regardless of the doubts about Homer's existence, one thing is certain: he never was a mapmaker. The enclosed map, which represents the conjectural view of the Homeric world, was never created by him. It is an imaginary reconstruction of the world as Homer described it in his two poems the Iliad and the Odyssey. It is worth mentioning that each of these writings involves strong geographic symbolism. They can be seen as descriptive pictures of life and warfare in the Bronze Age and the illustrated plans of real journeys. Thus, each one develops a philosophical view of the world, which makes it possible to show this information in the form of a map.

The depiction of the earth conceived by Homer, which was accepted by the early Greeks, represents a circular flat disk surrounded by a constantly moving stream of Ocean (Brown, 22), an idea which would be suggested by the appearance of the horizon as it is seen from a mountaintop or from a seacoast. Homer's knowledge of the Earth was very limited. He and his Greek contemporaries knew very little of the earth beyond Egypt as far south as the Libyan desert, the south-west coast of Asia Minor, and the northern boundary of the Greek homeland. Furthermore, the coast of the Black Sea was only known through myths and legends that circulated during his time. In his poems there is no mention of Europe and Asia as geographical concepts (Thompson, 21). That is why the big part of Homer's world that is portrayed on this interpretive map represents lands that border on the Aegean Sea. It is worth noting that even though Greeks believed that they were in the middle of the earth, they also thought that the edges of the world's disk were inhabited by savage, monstrous barbarians and strange animals and monsters; Homer's Odyssey mentions a great many of them.

Additional statements about ancient geography may be found in Hesiod's poems, probably written during the 8th century BC (Kirsh, 1). Through the lyrics of Works and Days and Theogony he shows to his contemporaries some definite geographical knowledge. He introduces the names of such rivers as Nile, Ister (Danube), the shores of the Bosphorus, and the Euxine (Black Sea), the coast of Gaul, the island of Sicily, and a few other regions and rivers

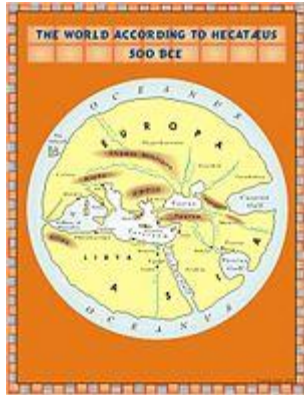
(Keane, 6–7). His advanced geographical knowledge not only had predated Greek colonial expansions, but also was used in the earliest Greek world maps, produced by Greek mapmakers such as Anaximander and Hecataeus of Miletus.

Early Greek maps

In classical antiquity, maps were drawn by Anaximander, Hecataeus of Miletus, Herodotus, Eratosthenes, and Ptolemy using both observations by explorers and a mathematical approach.

Early steps in the development of intellectual thought in ancient Greece belonged to Ionians from their well-known city of Miletus in Asia Minor. Miletus was placed favourably to absorb aspects of Babylonian knowledge and to profit from the expanding commerce of the Mediterranean. The earliest ancient Greek who is said to have constructed a map of the world is Anaximander of Miletus (c. 611–546 BC), pupil of Thales. He believed that the earth was a cylindrical form, like a stone pillar and suspended in space.[12] The inhabited part of his world was circular, disk-shaped, and presumably located on the upper surface of the cylinder (Brown, 24).

Anaximander was the first ancient Greek to draw a map of the known world. It is for this reason that he is considered by many to be the first mapmaker (Dilke, 23). A scarcity of archaeological and written evidence prevents us from giving any assessment of his map. What we may presume is that he portrayed land and sea in a map form. Unfortunately, any definite geographical knowledge that he included in his map is lost as well. Although the map has not survived, Hecataeus of Miletus (550–475 BC) produced another map fifty years later that he claimed was an improved version of the map of his illustrious predecessor.

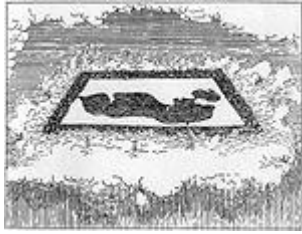


The world according to Hecataeus, 500 BC

Hecataeus's map describes the earth as a circular plate with an encircling Ocean and Greece in the centre of the world. This was a very popular contemporary Greek worldview, derived originally from the Homeric poems. Also, similar to many other early maps in antiquity his map has no scale. As units of measurements, this map used "days of sailing" on the sea and "days of marching" on dry land (Goode, 2). The purpose of this map was to accompany Hecataeus's geographical work that was called *Periodos Ges*, or *Journey Round the World* (Dilke, 24). *Periodos Ges* was divided into two books, "Europe" and "Asia", with the latter including Libya, the name of which was an ancient term for all of the known Africa.

The work follows the assumption of the author that the world was divided into two continents, Asia and Europe. He depicts the line between the Pillars of Hercules through the Bosporus, and the Don River as a boundary between the two. Hecataeus is the first known writer who thought that the Caspian flows into the circumference ocean—an idea that persisted long into the Hellenic period. He was particularly informative on the Black Sea, adding many geographic places that already were known to Greeks through the colonization process. To the north of the Danube, according to Hecataeus, were the Rhipæan (gusty) Mountains, beyond which lived the Hyperboreans—peoples of the far north. Hecataeus depicted the origin of the Nile River at the southern circumference ocean. His view of the Nile seems to have been that it came from the southern circumference ocean. This assumption helped Hecataeus solve the mystery of the annual flooding of the Nile. He believed that the waves of the ocean were a primary cause of this occurrence (Tozer, 63). It is worth mentioning that a similar map based upon one designed by Hecataeus was intended to aid political decision-making. According to Herodotus, it was

engraved upon a bronze tablet and was carried to Sparta by Aristagoras during the revolt of the Ionian cities against Persian rule from 499 to 494 BC.



The world according to Anaximenes, c. 500 BC

Anaximenes of Miletus (6th century BC), who studied under Anaximander, rejected the views of his teacher regarding the shape of the earth and instead, he visualized the earth as a rectangular form supported by compressed air.

Pythagoras of Samos (c. 560–480 BC) speculated about the notion of a spherical earth with a central fire at its core. He is also credited with the introduction of a model that divides a spherical earth into five zones: one hot, two temperate, and two cold—northern and southern.[citation needed] It seems likely that he illustrated his division in the form of a map, however, no evidence of this has survived to the present.

Scylax, a sailor, made a record of his Mediterranean voyages in c. 515 BC. This is the earliest known set of Greek periploi, or sailing instructions, which became the basis for many future mapmakers, especially in the medieval period.

The way in which the geographical knowledge of the Greeks advanced from the previous assumptions of the Earth's shape was through Herodotus and his conceptual view of the world. This map also did not survive and many have speculated that it was never produced. A possible reconstruction of his map is displayed below.



The world according to Herodotus, 440 BC

Herodotus traveled very extensively, collecting information and documenting his findings in his books on Europe, Asia, and Libya. He also combined his knowledge with what he learned from the people he met. Herodotus wrote his Histories in the mid-5th century BC. Although his work was dedicated to the story of long struggle of the Greeks with the Persian Empire, Herodotus also included everything he knew about the geography, history, and peoples of the world. Thus, his work provides a detailed picture of the known world of the 5th century BC.

Herodotus rejected the prevailing view of most 5th century BC maps that the earth is a circular plate surrounded by Ocean. In his work he describes the earth as an irregular shape with oceans surrounding only Asia and Africa. He introduces names such as the Atlantic Sea and the Erythraean Sea. He also divided the world into three continents: Europe, Asia, and Africa. He depicted the boundary of Europe as the line from the Pillars of Hercules through the Bosphorus and the area between Caspian Sea and Indus River. He regarded the Nile as the boundary between Asia and Africa. He speculated that the extent of Europe was much greater than was assumed at the time and left Europe's shape to be determined by future research.

In the case of Africa, he believed that, except for the small stretch of land in the vicinity of Suez, the continent was in fact surrounded by water. However, he definitely disagreed with his predecessors and contemporaries about its presumed circular shape. He based his theory on the story of Pharaoh Necho II, the ruler of Egypt between 609 and 594 BC, who had sent Phoenicians to circumnavigate Africa. Apparently, it took them three years, but they certainly did prove his idea. He speculated that the Nile River started as far west as the Ister River in Europe and cut Africa through the middle. He was the first writer to assume that the Caspian Sea was separated from other seas and he recognised northern Scythia as one of the coldest inhabited lands in the world.

Similar to his predecessors, Herodotus also made mistakes. He accepted a clear distinction between the civilized Greeks in the centre of the earth and the barbarians on the world's edges. In his Histories we can see very clearly that he believed that the world became stranger and stranger when one traveled away from Greece, until one reached the ends of the earth, where humans behaved as savages.

Spherical Earth and meridians

Whereas a number of previous Greek philosophers presumed the earth to be spherical, Aristotle (384–322 BC) is the one to be credited with proving the Earth's sphericity. Those arguments may be summarized as follows:

- The lunar eclipse is always circular
- Ships seem to sink as they move away from view and pass the horizon
- Some stars can be seen only from certain parts of the Earth.

A vital contribution to mapping the reality of the world came with a scientific estimate of the circumference of the earth. This event has been described as the first scientific attempt to give geographical studies a mathematical basis. The man credited for this achievement was Eratosthenes (275–195 BC). As described by George Sarton, historian of science, “there was among them [Eratosthenes's contemporaries] a man of genius but as he was working in a new field they were too stupid to recognize him” (Noble, 27). His work, including *On the Measurement of the Earth* and *Geographica*, has only survived in the writings of later philosophers such as Cleomedes and Strabo. He was a devoted geographer who set out to reform and perfect the map of the world. Eratosthenes argued that accurate mapping, even if in two dimensions only, depends upon the establishment of accurate linear measurements. He was the first to calculate the circumference of the Earth (within 0.5 percent accuracy) by calculating the heights of shadows on different parts of the Egypt at a given time. The first in Alexandria, the other further up the Nile, in the Ancient Egyptian city of Swenet (known in Greek as Syene) where reports of a well into which the sun shone only on the summer solstice, long existed. Proximity to the Tropic of Cancer being the dynamics creating the effect. He had the distance

between the two shadows calculated and then their height. From this he determined the difference in angle between the two points and calculated how large a circle would be made by adding in the rest of the degrees to 360. His great achievement in the field of cartography was the use of a new technique of charting with meridians, his imaginary north–south lines, and parallels, his imaginary west–east lines.[14] These axis lines were placed over the map of the earth with their origin in the city of Rhodes and divided the world into sectors. Then, Eratosthenes used these earth partitions to reference places on the map. He also was the first person to divide Earth correctly into five climatic regions: a torrid zone across the middle, two frigid zones at extreme north and south, and two temperate bands in between.[citation needed] He was also the first person to use the word "geography".

Claudius Ptolemy (90–168) thought that, with the aid of astronomy and mathematics, the earth could be mapped very accurately. Ptolemy revolutionized the depiction of the spherical earth on a map by using perspective projection, and suggested precise methods for fixing the position of geographic features on its surface using a coordinate system with parallels of latitude and meridians of longitude.[5][15]

Ptolemy's eight-volume atlas *Geographia* is a prototype of modern mapping and GIS. It included an index of place-names, with the latitude and longitude of each place to guide the search, scale, conventional signs with legends, and the practice of orienting maps so that north is at the top and east to the right of the map—an almost universal custom today.

Yet with all his important innovations, however, Ptolemy was not infallible. His most important error was a miscalculation of the circumference of the earth. He believed that Eurasia covered 180° of the globe, which convinced Christopher Columbus to sail across the Atlantic to look for a simpler and faster way to travel to India. Had Columbus known that the true figure was much greater, it is conceivable that he would never have set out on his momentous voyage.

Roman Empire



Reconstruction of Pomponius Mela's world view.

Pomponius Mela (c. 43)

Main article: Pomponius Mela

Pomponius is unique among ancient geographers in that, after dividing the earth into five zones, of which two only were habitable, he asserts the existence of antichthones, inhabiting the southern temperate zone inaccessible to the folk of the northern temperate regions from the unbearable heat of the intervening torrid belt. On the divisions and boundaries of Europe, Asia and Africa, he repeats Eratosthenes; like all classical geographers from Alexander the Great (except Ptolemy) he regards the Caspian Sea as an inlet of the Northern Ocean, corresponding to the Persian Gulf and the Red Sea on the south.



The Roman Tabula Peutingeriana.

5th-century Roman road map

In 2007, the Tabula Peutingeriana, a 12th-century replica of a 5th-century map, was placed on the UNESCO Memory of the World Register and displayed to the public for the first time.

Although well preserved and believed to be an accurate copy of an authentic original, the scroll media it is on is so delicate now it must be protected at all times from exposure to daylight.

CHINA

Earliest extant maps from the Qin State

The earliest known maps to have survived in China date to the 4th century BC. In 1986, seven ancient Chinese maps were found in an archeological excavation of a Qin State tomb in what is now Fangmatan, in the vicinity of Tianshui City, Gansu province. Before this find, the earliest extant maps that were known came from the Mawangdui excavation in 1973, which found three maps on silk dated to the 2nd century BC in the early Han Dynasty. The 4th century BCE maps from the State of Qin were drawn with black ink on wooden blocks. These blocks fortunately survived in soaking conditions due to underground water that had seeped into the tomb; the quality of the wood had much to do with their survival. After two years of slow-drying techniques, the maps were fully restored.

The territory shown in the seven Qin maps overlap each other. The maps display tributary river systems of the Jialing River in Sichuan province, in a total measured area of 107 by 68 km. The maps featured rectangular symbols encasing character names for the locations of administrative counties. Rivers and roads are displayed with similar line symbols; this makes interpreting the map somewhat difficult, although the labels of rivers placed in order of stream flow are helpful to modern day cartographers. These maps also feature locations where different types of timber can be gathered, while two of the maps state the distances in mileage to the timber sites. In light of this, these maps are perhaps the oldest economic maps in the world since they predate Strabo's economic maps.

In addition to the seven maps on wooden blocks found at Tomb 1 of Fangmatan, a fragment of a paper map was found on the chest of the occupant of Tomb 5 of Fangmatan in 1986. This tomb is dated to the early Western Han, so the map dates to the early 2nd century BC. The map shows topographic features such as mountains, waterways and roads, and is thought to cover the area of the preceding Qin Kingdom.

Earliest geographical writing

In China, the earliest known geographical Chinese writing dates back to the 5th century BC, during the beginning of the Warring States (481–221 BC) This was the 'Yu Gong' ('Tribute of Yu') chapter of the book Shu Jing (Classic of History). The book describes the traditional nine provinces, their kinds of soil, their characteristic products and economic goods, their tributary goods, their trades and vocations, their state revenues and agricultural systems, and the various rivers and lakes listed and placed accordingly The nine provinces in the time of this geographical work was very small in terrain size compared to what modern China occupies today. In fact, its description pertained to areas of the Yellow River, the lower valleys of the Yangtze, with the plain between them and the Shandong Peninsula, and to the west the most northern parts of the Wei River and the Han River were known (along with the southern parts of modern day Shanxi province)

Earliest known reference to a map, or 'tu'

The oldest reference to a map in China comes from the 3rd century BC. This was the event of 227 BC where Crown Prince Dan of Yan had his assassin Jing Ke visit the court of the ruler of the State of Qin, who would become Qin Shi Huang (r. 221–210 BC). Jing Ke was to present the ruler of Qin with a district map painted on a silk scroll, rolled up and held in a case where he hid his assassin's dagger Handing to him the map of the designated territory was the first diplomatic act of submitting that district to Qin rule.[25]Instead he attempted to kill Qin, an assassination plot that failed. From then on maps are frequently mentioned in Chinese sources.

Han Dynasty and period of division



An early Western Han Dynasty (202 BC – 9 AD) silk map found in tomb 3 of Mawangdui, depicting the Kingdom of Changsha and Kingdom of Nanyue in southern China (note: the south direction is oriented at the top, north at the bottom).

The three Han Dynasty maps found at Mawangdui differ from the earlier Qin State maps. While the Qin maps place the cardinal direction of north at the top of the map, the Han maps are orientated with the southern direction at the top. The Han maps are also more complex, since they cover a much larger area, employ a large number of well-designed map symbols, and include additional information on local military sites and the local population. The Han maps also note measured distances between certain places, but a formal graduated scale and rectangular grid system for maps would not be used—or at least described in full—until the 3rd century (see Pei Xiu below). Among the three maps found at Mawangdui was a small map representing the tomb area where it was found, a larger topographical map showing the Han's borders along the subordinate Kingdom of Changsha and the Nanyue kingdom (of northern Vietnam and parts of modern Guangdong and Guangxi), and a map which marks the positions of Han military garrisons that were employed in an attack against Nanyue in 181 BC.

An early text that mentioned maps was the Rites of Zhou. Although attributed to the era of the Zhou Dynasty, its first recorded appearance was in the libraries of Prince Liu De (c. 130 BC), and was compiled and commented on by Liu Xin in the 1st century AD. It outlined the use of maps that were made for governmental provinces and districts, principalities, frontier boundaries, and even pinpointed locations of ores and minerals for mining facilities. Upon the investiture of

three of his sons as feudal princes in 117 BC, Emperor Wu of Han had maps of the entire empire submitted to him

From the 1st century AD onwards, official Chinese historical texts contained a geographical section (Diliji), which was often an enormous compilation of changes in place-names and local administrative divisions controlled by the ruling dynasty, descriptions of mountain ranges, river systems, taxable products, etc. From the time of the 5th century BC Shu Jing forward, Chinese geographical writing provided more concrete information and less legendary element. This example can be seen in the 4th chapter of the Huainanzi (Book of the Master of Huainan), compiled under the editorship of Prince Liu An in 139 BC during the Han Dynasty (202 BC–202 AD). The chapter gave general descriptions of topography in a systematic fashion, given visual aids by the use of maps (di tu) due to the efforts of Liu An and his associate Zuo Wu. In Chang Chu's Hua Yang Guo Chi (Historical Geography of Szechuan) of 347, not only rivers, trade routes, and various tribes were described, but it also wrote of a 'Ba June Tu Jing' ('Map of Szechuan'), which had been made much earlier in 150

Local mapmaking such as the one of Szechuan mentioned above, became a widespread tradition of Chinese geographical works by the 6th century, as noted in the bibliography of the Sui Shu It is during this time of the Southern and Northern Dynasties that the Liang Dynasty (502–557) cartographers also began carving maps into stone steles (alongside the maps already drawn and painted on paper and silk)

Pei Xiu, the 'Ptolemy of China'

In the year 267, Pei Xiu (224–271) was appointed as the Minister of Works by Emperor Wu of Jin, the first emperor of the Jin Dynasty. Pei is best known for his work in cartography. Although map making and use of the grid existed in China before him he was the first to mention a plotted geometrical grid and graduated scale displayed on the surface of maps to gain greater accuracy in the estimated distance between different locations. Pei outlined six principles that should be observed when creating maps, two of which included the rectangular grid and the graduated scale for measuring distance. Historians compare him to the Greek Ptolemy for his contributions in cartography. However, Howard Nelson states that, although the accounts of earlier

cartographic works by the inventor and official Zhang Heng (78–139) are somewhat vague and sketchy, there is ample written evidence that Pei Xiu derived the use of the rectangular grid reference from the maps of Zhang Heng

Later Chinese ideas about the quality of maps made during the Han Dynasty and before stem from the assessment given by Pei Xiu, which was not a positive one. Pei Xiu noted that the extant Han maps at his disposal were of little use since they featured too many inaccuracies and exaggerations in measured distance between locations. However, the Qin State maps and Mawangdui maps of the Han era were far superior in quality than those examined by Pei Xiu. It was not until the 20th century that Pei Xiu's 3rd century assessment of earlier maps' dismal quality would be overturned and disproven. The Qin and Han maps did have a degree of accuracy in scale and pinpointed location, but the major improvement in Pei Xiu's work and that of his contemporaries was expressing topographical elevation on maps.

Sui and Tang dynasties

In the year 605, during the Sui Dynasty (581–618), the Commercial Commissioner Pei Ju (547–627) created a famous geometrically gridded map. In 610, Emperor Yang of Sui ordered government officials from throughout the empire to document in gazetteers the customs, products, and geographical features of their local areas and provinces, providing descriptive writing and drawing them all onto separate maps, which would be sent to the imperial secretariat in the capital city.

The Tang Dynasty (618–907) also had its fair share of cartographers, including the works of Xu Jingzong in 658, Wang Mingyuan in 661, and Wang Zhongsi in 747. Arguably the greatest geographer and cartographer of the Tang period was Jia Dan (730–805), whom Emperor Dezong of Tang entrusted in 785 to complete a map of China with her recently former inland colonies of Central Asia, the massive and detailed work completed in 801, called the *Hai Nei Hua Yi Tu* (Map of both Chinese and Barbarian Peoples within the (Four) Seas). The map was 30 ft long (9.1 m) and 33 ft high (10 m) in dimension, mapped out on a grid scale of 1-inch (25 mm) equaling 100 li (unit) (the Chinese equivalent of the mile/kilometer). Jia Dan is also known for having described the Persian Gulf region with great detail, along with lighthouses that were

erected at the mouth of the Persian Gulf by the medieval Iranians in the Abbasid period (refer to article on Tang Dynasty for more).

Song Dynasty

During the Song Dynasty (960–1279) Emperor Taizu of Song ordered Lu Duosun in 971 to update and 're-write all the Tu Jing in the world', which would seem to be a daunting task for one individual, who was sent out throughout the provinces to collect texts and as much data as possible. With the aid of Song Zhun, the massive work was completed in 1010, with some 1566 chapters. The later Song Shi historical text stated (Wade-Giles spelling):

“ Yuan Hsieh (d. +1220) was Director-General of governmental grain stores. In pursuance of his schemes for the relief of famines he issued orders that each pao (village) should prepare a map which would show the fields and mountains, the rivers and the roads in fullest detail. The maps of all the pao were joined together to make a map of the tu (larger district), and these in turn were joined with others to make a map of the hsiang and the hsien (still larger districts). If there was any trouble about the collection of taxes or the distribution of grain, or if the question of chasing robbers and bandits arose, the provincial officials could readily carry out their duties by the aid of the maps. ”



The Yu Ji Tu, or Map of the Tracks of Yu Gong, carved into stone in 1137, located in the Stele Forest of Xian. This 3 ft (0.91 m) squared map features a graduated scale of 100 li for each rectangular grid. China's coastline and river systems are clearly defined and precisely pinpointed

on the map. Yu Gong is in reference to the Chinese deity described in the geographical chapter of the Classic of History, dated 5th century BC.

Like the earlier Liang Dynasty stone-stele maps (mentioned above), there were large and intricately carved stone stele maps of the Song period. For example, the 3 ft (0.91 m) squared stone stele map of an anonymous artist in 1137, following the grid scale of 100 li squared for each grid square. What is truly remarkable about this map is the incredibly precise detail of coastal outlines and river systems in China (refer to Needham's Volume 3, Plate LXXXI for an image). The map shows 500 settlements and a dozen rivers in China, and extends as far as Korea and India. On the reverse, a copy of a more ancient map uses grid coordinates in a scale of 1:1,500,000 and shows the coastline of China with great accuracy.

The famous 11th century scientist and polymath statesman Shen Kuo (1031–1095) was also a geographer and cartographer. His large atlas included twenty three maps of China and foreign regions that were drawn at a uniform scale of 1:900,000. Shen also created a three-dimensional raised-relief map using sawdust, wood, beeswax, and wheat paste, while representing the topography and specific locations of a frontier region to the imperial court. Shen Kuo's contemporary, Su Song (1020–1101), was a cartographer who created detailed maps in order to resolve a territorial border dispute between the Song Dynasty and the Liao Dynasty.

Ming and Qing dynasties

The Da Ming hunyi tu map, dating from about 1390, is in multicolour. The horizontal scale is 1:820,000 and the vertical scale is 1:1,060,000.

In 1579, Luo Hongxian published the Guang Yutu atlas, including more than 40 maps, a grid system, and a systematic way of representing major landmarks such as mountains, rivers, roads and borders. The Guang Yutu incorporates the discoveries of naval explorer Zheng He's 15th century voyages along the coasts of China, Southeast Asia, India and Africa.

From the 16th and 17th centuries, several examples survive of maps focused on cultural information. Gridlines are not used on either Yu Shi's Gujin xingsheng zhi tu (1555) or Zhang Huang's Tushu bian (1613); instead, illustrations and annotations show mythical places, exotic

foreign peoples, administrative changes and the deeds of historic and legendary heroes. Also in the 17th century, an edition of a possible Tang Dynasty map shows clear topographical contour lines.[48] Although topographic features were part of maps in China for centuries, a Fujian county official Ye Chunji (1532–1595) was the first to base county maps using on-site topographical surveying and observations.[49]

The Korean made Kangnido based on two Chinese maps, which describes the Old World.

MONGOL EMPIRE

In the Mongol Empire, the Mongol scholars with the Persian and Chinese cartographers or their foreign colleagues created maps, geographical compendium as well as travel accounts. Rashid-al-Din Hamadani described his geographical compendium, "Suvar al-aqalim", constituted volume four of the Collected chronicles of the Ilkhanate in Persia. His works say about the borders of the seven climes (old world), rivers, major cities, places, climate, and Mongol yams (relay stations). The Great Khan Khubilai's ambassador and minister, Bolad, had helped Rashid's works in relation to the Mongols and Mongolia. Thanks to Pax Mongolica, the easterners and the westerners in Mongol dominions were able to gain access to one another's geographical materials.

The Mongols required the nations they conquered to send geographical maps to the Mongol headquarters.

One of medieval Persian work written in northwest Iran can clarify the historical geography of Mongolia where Genghis Khan was born and united the Mongol and Turkic nomads as recorded in native sources, especially the Secret History of the Mongols

Map of relay stations, called "yam", and strategic points existed in the Yuan Dynasty. The Mongol cartography was enriched by traditions of ancient China and Iran which were now under the Mongols.

Because the Yuan court often requested the western Mongol khanates to send their maps, the Yuan Dynasty was able to publish a map describing the whole Mongol world in c.1330. This is

called "Hsi-pei pi ti-li tu". The map includes the Mongol dominions including 30 cities in Iran such as Ispahan and the Ilkhanid capital Soltaniyeh, and Russia (as "Orash") as well as their neighbors, e.g. Egypt and Syria

INDIA



The pundit (explorer)cartographer Nain Singh Rawat(19th century) received a Royal Geographical Society gold medal in 1876.

Main article: Cartography of India

Indian cartographic traditions covered the locations of the Pole star and other constellations of use. These charts may have been in use by the beginning of the Common Era for purposes of navigation

Detailed maps of considerable length describing the locations of settlements, sea shores, rivers, and mountains were also made. The 8th century scholar Bhavabhuti conceived paintings which indicated geographical regions.

European scholar Francesco I reproduced a number of ancient Indian maps in his magnum opus *La Cartografia Antica dell India*. Out these maps, two have been reproduced using a manuscript

of Lokaprakasa, originally compiled by the polymath Ksemendra (Kashmir, 11th century), as a source. The other manuscript, used as a source by Francesco I, is titled Samgrahani. The early volumes of the Encyclopædia Britannica also described cartographic charts made by the Dravidian people of India.

Maps from the Ain-e-Akbari, a Mughal document detailing India's history and traditions, contain references to locations indicated in earlier Indian cartographic traditions. Another map describing the kingdom of Nepal, four feet in length and about two and a half feet in breadth, was presented to Warren Hastings. In this map the mountains were elevated above the surface, and several geographical elements were indicated in different colors.

Chapter 3

Animated Mapping

Animated mapping is the application of animation, either computer or video, to add a temporal component to a map displaying change in some dimension. Most commonly the change is shown over time, generally at a greatly changed scale (either much faster than real time or much slower). An example would be the animation produced after the 2004 Tsunami showing how the waves spread across the Indian Ocean.

The concept of animated maps began in the 1930s, but did not become more developed by cartographers until the 1950s (Slocum et al. 2005). In 1959, Norman Thrower published *Animated Cartography*, discussing the use of animated maps in adding a new dimension that was difficult to express in static maps: time. These early maps were created by drawing "snap-shots" of static maps, putting a series of maps together to form a scene and creating animation through photography tricks (Thrower 1959). Such early maps rarely had an associated scale, legends or oriented themselves to lines of longitude or latitude (Campbell and Egbert 1990).

With the development of computers in the 1960s and 1970s, animation programs were developed allowing the growth of animation in mapping. Waldo Tobler created one of the first animations, using a 3-D computer generated map to portray population growth over a specified time in Detroit (Tobler 1970). Hal Moellering created another animated map in 1976 representing a spatiotemporal pattern in traffic accidents (Slocum et al. 2005).

Further development in animated map was stalled until the 1990s due to a lack of animation in academics, financial restrictions on research, and lack of distribution means (Campbell and Egbert 1990). In the 1990s, however, the invention of faster, more efficient computers, compact discs and the Internet solved such problems.

With the growth of animated mapping came the development of guidelines for creating animated maps. Visual variables such as spacing, lightness and shape used for static maps apply. However, in 1991, David DiBiase and colleagues developed visual variables unique to animated maps: duration, rate of change and order. Duration is the unit of time a frame or scene is displayed, affecting the smoothness of the animation. The shorter a frame is displayed, the smoother the animation will appear (Slocum et al. 2005). Smoothness of animation is also a function of the rate of change (Slocum et al. 2005). Order refers to the time sequence in which animation is played out, usually presented in chronological sequence (Slocum et al. 2005). Alan MacEachren extended these visual variables in 1995 to include display date (time at which change is initiated), frequency (number of times identifiable forms are displayed) and synchronization (correspondence of 2 or more time series) (Slocum et al. 2005).

TYPES OF ANIMATED MAPS

Animated maps can emphasize the existence of an occurrence at a location, emphasize an attribute of an occurrence or representing change in the position or attributes of an occurrence (DiBiase 1992). For instance, a flashing symbol may be used to draw the map-reader's attention to a particular occurrence at one location or multiple location across the map. Maps on the weather channel use animation to emphasize current and predicted paths of hurricanes.

The use of the Internet has allowed animated maps to become interactive. The user can witness representations of changes over time, while manipulating the direction of view, the pace or the parameters of the map displayed (MacEachren 1998).

Animation on Maps can be mainly divided into two types:

Temporal Animation: Temporal shows the ongoing gradual changes over time. Temporal maps can also be termed as animated timeline maps and can be a useful reference to examine the changes ongoing on each step and analyze the progression occurring gradually as time passes.

There are many purposes which temporal animation might serve to depict: displaying and analyzing geographic patterns, meteorological events, climate, natural disasters, and other multivariate data.

Importance of Legend in Temporal Maps: As in the case of static maps, it would be useful if temporal maps could also be provided with proper legend. Legends for temporal maps should not only tell the time but also let user travel over the time. Various manipulations such as traveling to a certain point in time, selecting focus level etc. should be allowed to enhance user friendliness.

Using legend in temporal map will answer important questions related to the entity's existence (if?), the entity's location (when?), time intervals (how long?), temporal texture (how often), speed at which change takes place (how fast?), and the order of change (what order?) (MacEachren, 1995).

Depending upon their construction, animated legends may distract the viewer from the animated map. Care must be taken to integrate the legend in an unobtrusive fashion.

Non-Temporal Animation: Non-Temporal Animation shows changes against some other variables other than time. The variable might be place, position, generalization level etc. Non – temporal animation also serves when there is a need to show both the data set and the transformation that has been applied on it for its display.

Non- temporal animation can be of many types according to the purpose they serve:

- 1) Fly thorough animation: This type of animation gives the viewer the feeling of flying through the landscape.
- 2) Cartographic zoom animation: This type of animation shows maps at different focus level and viewer can change the scale of the map as desired.
- 3) Classification animation: Different methods of data classification are depicted in this animation.
- 4) Generalization animation: This type of animation uses single classification method with multiple classes of data.
- 5) Time is an important aspect in both animations. Real time is depicted in temporal animation and presentation time (time to show the animation) is associated with non-temporal animation.

Chapter 4

Counter Mapping

Counter-mapping refers to efforts to map "against dominant power structures, to further seemingly progressive goals". The term was coined by Nancy Peluso in 1995 to describe the commissioning of maps by forest users in Kalimantan, Indonesia, as a means of contesting state maps of forest areas that typically undermined indigenous interests. The resultant counter-hegemonic maps had the ability to strengthen forest users' resource claims. There are numerous expressions closely related to counter-mapping: ethnocartography, alternative cartography, mapping-back, counter-hegemonic mapping, and public participatory mapping. Moreover, the terms: critical cartography, subversive cartography, bioregional mapping, and remapping are sometimes used synonymously with counter-mapping, but in practice encompass much more.

Whilst counter-mapping still primarily refers to indigenous cartographic efforts, it is increasingly being applied to non-indigenous mapping initiatives in economically developed countries. Such counter-mapping efforts have been facilitated by processes of neoliberalism, and technological democratisation. Examples of counter-mapping include attempts to demarcate and protect traditional territories, community mapping, Public Participatory Geographical Information Systems, and mapping by a relatively weak state to counter the resource claims of a stronger state. The power of counter-maps to advocate policy change in a bottom-up manner led commentators to affirm that counter-mapping should be viewed as a tool of governance.

Despite its emancipatory potential, counter-mapping has not gone without criticism. There is a tendency for counter-mapping efforts to overlook the knowledge of women, minorities, and other vulnerable, disenfranchised groups. From this perspective, counter-mapping is only empowering for a small subset of society, whilst others become further marginalised.

Nancy Peluso, Professor of forest policy, coined the term 'counter-mapping' in 1995, having examined the implementation of two forest mapping strategies in Kalimantan. One set of maps belonged to state forest managers, and the international financial institutions that supported them, such as the World Bank. This strategy recognised mapping as a means of protecting local claims

to territory and resources to a government that had previously ignored them. The other set of maps had been created by Indonesian NGOs, who often contract international experts to assist with mapping village territories.[2] The goal of the second set of maps was to co-opt the cartographic conventions of the Indonesian state, to legitimise the claims by the Dayak people, indigenous to Kalimantan, to the rights to forest use.[3] Counter-mappers in Kalimantan have acquired GIS technologies, satellite technology, and computerised resource management tools, consequently making the Indonesian state vulnerable to counter-maps. As such, counter-mapping strategies in Kalimantan have led to successful community action to block, and protest against, oil palm plantations and logging concessions imposed by the central government. It must, however, be recognised that counter-mapping projects existed long before coinage of the term. Counter-maps are rooted in map art practices that date to the early 20th century; in the mental maps movement of the 1960s; in indigenous and bioregional mapping; and parish mapping.

Parish Maps Project

In 1985, the charity Common Ground launched the Parish Maps Project, a bottom-up initiative encouraging local people to map elements of the environment valued by their parish. Since then, more than 2,500 English parishes have made such maps. Parish mapping projects aim to put every local person in an 'expert' role. Clifford exemplifies this notion, affirming: "making a parish map is about creating a community expression of values, and about beginning to assert ideas for involvement. It is about taking the place in your own hands". The final map product is typically an artistic artefact, usually painted, and often displayed in village halls or schools. By questioning the biases of cartographic conventions and challenging predominant power effects of mapping, The Parish Maps Project is an early example of what Peluso went on to term 'counter-mapping'

DEVELOPMENT

NEOLIBERALISM

The development of counter-mapping can be situated within the neoliberal political-economic restructuring of the state. Prior to the 1960s, equipping a map-making enterprise was chiefly the duty of a single agency, funded by the national government. In this sense, maps have

conventionally been the products of privileged knowledges. However, processes of neoliberalism, predominantly since the late 1970s, have reconfigured the state's role in the cartographic project. Neoliberalism denotes an emphasis on markets and minimal states, whereby individual choice is perceived to have replaced the mass-production of commodities. The fact that citizens are now performing cartographic functions that were once exclusively state-controlled can be partially explained through a shift from "roll-back neoliberalism", in which the state dismantled some of its functions, to "roll-out neoliberalism", in which new modes of operating have been constructed.[19] In brief, the state can be seen to have "hollowed out" and delegated some of its mapping power to citizens.

Counter-mapping as neoliberal governmentality

Governmentality refers to a particular form of state power that is exercised when citizens self-discipline by acquiescing to state knowledge. Historically, cartography has been a fundamental governmentality strategy, a technology of power, used for surveillance and control. Competing claimants and boundaries made no appearance on state-led maps. This links to Foucault's notion of "subjugated knowledges" - ones that did not rise to the top, or were disqualified. However, through neoliberalising processes, the state has retracted from performing some of its cartographic functions. Consequently, rather than being passive recipients of top-down map distribution, people now have the opportunity to claim sovereignty over the mapping process. In this new regime of neoliberal cartographic governmentality the "insurrection of subjugated knowledges" occurs, as counter-mapping initiatives incorporate previously marginalised voices.

Technological democratisation

In response to technological change, predominantly since the 1980s, cartography has increasingly been democratised. The wide availability of high-quality location information has enabled mass-market cartography based on Global Positioning System receivers, home computers, and the Internet. The fact that civilians are using technologies which were once elitist led Brosius et al. to assert that counter-mapping involves "stealing the master's tools". Nevertheless, numerous early counter-mapping projects successfully utilised manual techniques, and many still use them. For instance, in recent years, the use of simple sketch mapping

approaches has been revitalised, whereby maps are made on the ground, using natural materials. Similarly, the use of scale model constructions and felt boards, as means of representing cartographic claims of different groups, have become increasingly popular. Consequently, Wood et al. assert that counter-mappers can "make gateau out of technological crumbs".

Public Participation Geographical Information Systems

In recent years, Public Participation Geographical Information Systems (PPGIS) have attempted to take the power of the map out of the hands of the cartographic elite, putting it into the hands of the people. For instance, Kyem designed a PPGIS method termed Exploratory Strategy for Collaboration, Management, Allocation, and Planning (ESCMAP). The method sought to integrate the concerns and experiences of three rural communities in the Ashanti Region of Ghana into official forest management practices. Kyem concluded that, notwithstanding the potential of PPGIS, it is possible that the majority of the rich and powerful people in the area would object to some of the participatory uses of GIS. For example, loggers in Ghana affirmed that the PPGIS procedures were too open and democratic. Thus, despite its democratising potential, there are barriers to its implementation. More recently, Wood et al. disputed the notion of PPGIS entirely, affirming that it is "scarcely GIS, intensely hegemonic, hardly public, and anything but participatory".

Counter-mapping as governance

Governance makes problematic state-centric notions of regulation, recognising that there has been a shift to power operating across several spatial scales. Similarly, counter-mapping problematises state distribution of cartography, advocating bottom-up participatory mapping projects (see GIS and environmental governance). Counter-mapping initiatives, often without state assistance, attempt to exert power. As such, counter-mapping conforms to Jessop's notion of "governance without government". Another characteristic of governance is its "purposeful effort to steer, control or manage sectors or facets of society" towards a common goal. Likewise, as maps exude power and authority, they are a trusted medium[34] with the ability to 'steer' society in a particular direction. In brief, cartography, once the tool of kings and governments, is now

being used as a tool of governance - to advocate policy change from the grassroots. The environmental sphere is one context in which counter-mapping has been utilised as a governance tool.

Counter-mapping as environmental governance

In contrast to expert knowledges, lay knowledges are increasingly valuable to decision-makers, in part due to the scientific uncertainty surrounding environmental issues. Participatory counter-mapping projects are an effective means of incorporating lay knowledges into issues surrounding environmental governance. For instance, counter-maps depicting traditional use of areas now protected for biodiversity have been used to allow resource use, or to promote public debate about the issue, rather than forcing relocation. For example, the World Wide Fund for Nature used the results of counter-mapping to advocate for the reclassification of several strictly protected areas into Indonesian national parks, including Kayan Mentarang and Gunung Lorentz. The success of such counter-mapping efforts led Alcorn to affirm that governance (grassroots mapping projects), rather than government (top-down map distribution), offers the best hope for good natural resource management. In short, it can be seen that "maps are powerful political tools in ecological and governance discussions".

Types of counter-mapping

Numerous counter-mapping types exist, for instance: protest maps, map art, counter-mapping for conservation, and PPGIS. In order to emphasise the wide scope of what has come to be known as counter-mapping, three contrasting counter-mapping examples are elucidated in this section: indigenous counter-mapping, community mapping, and state counter-mapping, respectively.

Indigenous counter-mapping

Counter-mapping has been undertaken most in the Third World. Indigenous peoples are increasingly turning to participatory mapping, appropriating both the state's techniques and manner of representation. Counter-mapping is a tool for indigenous identity-building, and for

bolstering the legitimacy of customary resource claims. The success of counter-mapping in realising indigenous claims can be seen through Nietschmann's assertion:

More indigenous territory has been claimed by maps than by guns. And more Indigenous territory can be reclaimed and defended by maps than by guns.

Creation of Nunavut

The power of indigenous counter-mapping can be exemplified through the creation of Nunavut. In 1967, Frank Arthur Calder and the Nisaga'a Nation Tribal Council brought an action against the Province of British Columbia for a declaration that aboriginal title to specified land had not been lawfully extinguished. In 1973, the Canadian Supreme Court found that there was, in fact, an aboriginal title. The Canadian government attempted to extinguish such titles by negotiating treaties with the people who had not signed them. As a first step, the Inuit Tapirisat of Canada studied Inuit land occupancy in the Arctic, resulting in the publication of the Inuit Land Use and Occupancy Project. Diverse interests, such as those of hunters, trappers, fishermen and berry-pickers mapped out the land they had used during their lives.[9] As Usher noted

Community mapping

Community mapping can be defined as: "local mapping, produced collaboratively, by local people and often incorporating alternative local knowledge". OpenStreetMap is an example of a community mapping initiative, with the potential to counter the hegemony of state-dominated map distribution.

Open Street Map



OpenStreetMap home page.

OpenStreetMap (OSM), a citizen-led spatial data collection website, was founded by Steve Coast in 2004 (see right for OSM home page). Data are collected from diverse public domain sources; of which GPS tracks are the most important, collected by volunteers with GPS receivers. As of 10 January 2011 there were 340,522 registered OSM users, who had uploaded 2.121 billion GPS points onto the website. The process of map creation explicitly relies upon sharing and participation; consequently, every registered OSM user can edit any part of the map. Moreover, 'map parties' - social events which aim to fill gaps in coverage, help foster a community ethos. In short, the grassroots OSM project can be seen to represent a paradigm shift in who creates and shares geographic information - from the state, to society. However, rather than countering the state-dominated cartographic project, some commentators have affirmed that OSM merely replicates the 'old' socio-economic order. For instance, Hakla affirmed that OSM users in the United Kingdom tend not to map council estates; consequently, middle-class areas are disproportionately mapped. Thus, in opposition to notions that OSM is a radical cartographic counter-culture are contentions that OSM "simply recreates a mirror copy of existing topographic mapping"

State counter-mapping

What has come to be known as counter-mapping is not limited to the activities of non-state actors within a particular nation-state; relatively weak states also engage in counter-mapping in an attempt to challenge other states.

Competing cartographic representations: East Timor versus Australia

East Timor's on-going effort to gain control of gas and oil resources from Australia, which it perceives at its own, is a form of counter-mapping. This dispute involves a cartographic contestation of Australia's mapping of the seabed resources between the two countries. As Nevins contends: whilst Australia's map is based on the status quo - a legacy of a 1989 agreement between Australia and the Indonesian occupier of East Timor at that time, East Timor's map represents an enlarged notion of what its sea boundaries should be, thereby entailing a redrawing of the map. This form of counter-mapping thus represents a claim by a

relatively weak state, East Timor, to territory and resources that are controlled by a stronger state, Australia. However, Nevin notes that there is limited potential of realising a claim through East Timor's counter-map: counter-mapping is an effective strategy only when combined with broader legal and political strategies.

Criticisms

Counter-mapping's claim to incorporate counter-knowledges, and thereby empower traditionally disempowered people, has not gone uncontested. A sample of criticisms leveled at counter-mapping:

- Counter-mapping fails to recognise that community is a constantly shifting, fluid process, too often relying on a notion of community as bounded and fixed. As such, the process of mapping communicates and naturalises who does, and who does not, belong within particular boundaries.
- Due to the power imbalance between indigenous claims and those of the state, the language and tools of the dominant society must be used by those under its control. The process of using another's tools can change the ideas represented, resulting in a map of unpredictable quality.
- Counter-mapping is in danger of becoming the 'thing to do'; a "magic bullet applied uncritically".
- There is a geography to the success of counter-mapping. In Tibet, counter-mapping is of limited political utility as mapmaking is not enfranchised and cannot be scaled up, for instance, to settle legal battles over land tenure and resource rights through the regulatory offices of the state.
- Counter-mapping projects utilising GIS require significant knowledge and computer literacy above that of lay individuals.
- Investment in specialised computers and software often results in prohibitive mapping costs for a large majority of local people, particularly in poor areas. As some groups prove more capable of adopting the technologies than others, counter-mapping projects can deepen divisions within communities along gender and economic lines.

To summarise, whilst counter-mapping has the potential to transform map-making from "a science of princes" the investment required to create a map with the ability to challenge state-produced cartography means that counter-mapping is unlikely to become a "science of the masses".

CHAPTER5

IMAGERY INTELLIGENCE

Imagery intelligence (IMINT), is an intelligence gathering discipline which collects information via satellite and aerial photography. As a means of collecting intelligence, IMINT is a subset of intelligence collection management, which, in turn, is a subset of intelligence cycle management. IMINT is especially complemented by non-imaging MASINT electro-optical and radar sensors.

Aerial intelligence goes back to the mid-19th century. During the American Civil War, for example, hot air balloons were used to observe enemy formations far in the distance. In 1888 Amedee Denisse (France) studied the possibility of cameras attached to rockets to obtain photographic evidence over great distances; unfortunately this vision was likely never achieved in full. Shortly after the turn of the century, the introduction of pigeons with small cameras attached to their chests became a short-lived long-distance reconnaissance option, but with obvious flaws and difficulties. On the other hand, the 19th century use of fixed balloons survived into World War I, when it was accompanied by observation from airships (zeppelins) and the newly invented airplane. In WW2 a Joint Imagery Intelligence unit was set up in Danesfield House, Medmenham in Buckinghamshire, UK for British and US Intelligence Officers to exploit imagery gathered on the Germans.

Low- and high-flying planes have been used all through the last century to gather intelligence about the enemy. At the start of the Cold War, foreseeing the need to observe the enemy in peacetime as well as war, the U.S. developed high-flying reconnaissance planes. The first, the Lockheed U-2, is still in service; its successor, the newer, much faster SR-71 Blackbird, was retired in 1998. These planes have the advantage over satellites that they can usually produce more detailed photographs and can be placed over the target more quickly, more often, and more cheaply, but have the disadvantage of possibly being intercepted by aircraft or missiles such as in the 1960 U-2 incident.

A new generation of unmanned reconnaissance planes has been developed for imagery and signals intelligence. Known as Unmanned Aerial Vehicles, these drones are a force multiplier by

giving the battlefield commander an "eye in the sky" without risking a pilot. The US Army is significantly increasing the size of its current UAV force as part of the Future Combat System initiative.

Though the resolution of satellite photographs, which must be taken from distances of hundreds of kilometers, is usually poorer than photographs taken by air, satellites offer the possibility of coverage for much of the earth, including hostile territory, without exposing human pilots to the risk of being shot down.

There have been hundreds of reconnaissance satellites launched by dozens of nations since the first years of space exploration. While the information about the vast majority of such satellites are strictly classified, some information (such as that concerning the US Corona program) has been declassified with the end of the Cold War.

Early photographic reconnaissance satellites used photographic film, which was exposed on-orbit and returned to earth for developing. These satellites remained in orbit for days, weeks, or months before ejecting their film-return vehicles, called "buckets." Between 1959 and 1984 the U.S. launched around 200 such satellites under the codenames CORONA and GAMBIT, with ultimate photographic resolution (ground-resolution distance) better than 4 inches (0.10 m). The first successful mission concluded on 1960-08-19 with the mid-air recovery by a C-119 of film from the Corona mission code-named Discoverer 14. This was the first successful recovery of film from an orbiting satellite and the first aerial recovery of an object returning from Earth orbit. Because of a tradeoff between area covered and ground resolution, not all reconnaissance satellites have been designed for high resolution; the KH-5-ARGON program had a ground resolution of 140 meters and was intended for mapmaking.

Between 1961 and 1994 the USSR launched perhaps 500 Zenit film-return satellites, which returned both the film and the camera to earth in a pressurized capsule.

Satellites for imaging intelligence were usually placed in low-earth, high-inclination orbits, sometimes in sun-synchronous orbits. Since the film-return missions were usually short, they could indulge in orbits with low perigees, in the range of 100–200 km, but the more recent CCD-based satellites have been launched into higher orbits, 250–300 km perigee, allowing each to remain in orbit for several years. While the exact resolution and other details of modern spy

satellites are classified, some idea of the trade-offs available can be made using simple physics. The formula for the highest possible resolution of an optical system with a circular aperture is given by the Rayleigh criterion.

where θ is the angular resolution, λ is the wavelength of light, and D is the diameter of the lens or mirror. Were the Hubble Space Telescope, with a 2.4 m telescope, designed for photographing Earth, it would be diffraction-limited to resolutions greater than 16 cm (6 inches) for green light (500 nm) at its orbital altitude of 590 km. This means that it would be impossible to take photographs showing objects smaller than 16 cm with such a telescope at such an altitude. Modern U.S. IMINT satellites are believed to have around 10 cm resolution; contrary to references in popular culture, this is sufficient to detect any type of vehicle, but not to read the headlines of a newspaper.

The U.S. KH-11 series of satellites, first launched in 1976, was made by Lockheed, the same contractor who built the Hubble Space Telescope. HST has a 2.4 metre telescope mirror and is believed to have had a similar appearance to the KH-11 satellites. These satellites used charge-coupled devices, predecessors to modern digital cameras, rather than film. Russian reconnaissance satellites with comparable capabilities are named Resurs DK and Persona.

The primary purpose of most spy satellites is to monitor visible ground activity. While resolution and clarity of images has improved greatly over the years, this role has remained essentially the same. Some other uses of satellite imaging have been to produce detailed 3D maps for use in operations and missile guidance systems, and to monitor normally invisible information such as the growth levels of a country's crops or the heat given off by certain facilities. Some of the multi-spectral sensors, such as thermal measurement, are more electro-optical MASINT than true IMINT platforms.

To counter the threat posed by these 'eyes in the sky', the United States, USSR/Russia, China and possibly others, have developed systems for destroying enemy spy satellites (either with the use of another 'killer satellite', or with some sort of Earth- or air-launched missile).

Since 1985, commercial vendors of satellite imagery have entered the market, beginning with the French SPOT satellites, which had resolutions between 5 and 20 metres. Recent high-resolution (4 - 0.5 metre) private imaging satellites include TerraSAR-X, IKONOS, Orbview, QuickBird

and Worldview-1, allowing any country (or any business for that matter) to buy access to satellite images.

UAVs have developed until they span a spectrum of literally handheld imaging platforms for infantry tactical use, up to large multisensor platforms such as Global Hawk. Global Hawk, with its long loiter time and global reach, has some of the attributes of a satellite in a lower earth orbit than would be feasible for a true orbiter.

An unmanned aerial vehicle (UAV), commonly known as drone, is an aircraft without a human pilot on board. Its flight is controlled either autonomously by computers in the vehicle or under the remote control of a pilot on the ground or in another vehicle. The typical launch and recovery method of an unmanned aircraft is by the function of an automatic system or an external operator on the ground.

There are a wide variety of UAV shapes, sizes, configurations, and characteristics. Historically, UAVs were simple remotely piloted aircraft, but autonomous control is increasingly being employed.

They are usually deployed for military and special operation applications, but also used in a small but growing number of civil applications, such as policing and firefighting, and nonmilitary security work, such as surveillance of pipelines. UAVs are often preferred for missions that are too "dull, dirty or dangerous" for manned aircraft.

Chapter 6

Maps

A map is a visual representation of an area – symbolic depiction highlighting relationships between elements of that space such as objects, regions, and themes.

Many maps are static two-dimensional, geometrically accurate (or approximately accurate) representations of three-dimensional space, while others are dynamic or interactive, even three-dimensional. Although most commonly used to depict geography, maps may represent any space, real or imagined, without regard to context or scale; e.g. brain mapping, DNA mapping and extraterrestrial mapping.

Although the earliest maps known are of the heavens, geographic maps of territory have a very long tradition and exist from ancient times. The word "map" comes from the medieval Latin *Mappa mundi*, wherein *mappa* meant napkin or cloth and *mundi* the world. Thus, "map" became the shortened term referring to a 2 dimensional representation of the surface of the world.

Cartography or map-making is the study and practice of crafting representations of the Earth upon a flat surface (see History of cartography), and one who makes maps is called a cartographer.

Road maps are perhaps the most widely used maps today, and form a subset of navigational maps, which also include aeronautical and nautical charts, railroad network maps, and hiking and bicycling maps. In terms of quantity, the largest number of drawn map sheets is probably made up by local surveys, carried out by municipalities, utilities, tax assessors, emergency services providers, and other local agencies. Many national surveying projects have been carried out by the military, such as the British Ordnance Survey: a civilian government agency, internationally renowned for its comprehensively detailed work.

In addition to location information maps may also be used to portray contour lines indicating constant values of elevation, temperature, rainfall, etc.

The orientation of a map is the relationship between the directions on the map and the corresponding compass directions in reality. The word "orient" is derived from Latin *oriens*, meaning East. In the Middle Ages many maps, including the T and O maps, were drawn with

East at the top (meaning that the direction "up" on the map corresponds to East on the compass). Today, the most common – but far from universal – cartographic convention is that North is at the top of a map. Several kinds of maps are often traditionally not oriented with North at the top:

- Maps from non-Western traditions are oriented a variety of ways. Old maps of Edo show the Japanese imperial palace as the "top", but also at the centre, of the map. Labels on the map are oriented in such a way that you cannot read them properly unless you put the imperial palace above your head.
- Medieval European T and O maps such as the Hereford Mappa Mundi were centred on Jerusalem with East at the top. Indeed, prior to the reintroduction of Ptolemy's Geography to Europe around 1400, there was no single convention in the West. Portolan charts, for example, are oriented to the shores they describe.
- Maps of cities bordering a sea are often conventionally oriented with the sea at the top.
- Route and channel maps have traditionally been oriented to the road or waterway they describe.
- Polar maps of the Arctic or Antarctic regions are conventionally centred on the pole; the direction North would be towards or away from the centre of the map, respectively. Typical maps of the Arctic have 0° meridian towards the bottom of the page; maps of the Antarctic have the 0° meridian towards the top of the page.
- Reversed maps, also known as Upside-Down maps or South-Up maps, reverse the "North is up" convention and have South at the top.
- Buckminster Fuller's Dymaxion maps are based on a projection of the Earth's sphere onto an icosahedron. The resulting triangular pieces may be arranged in any order or orientation.
- Modern digital GIS maps such as ArcMap typically project north at the top of the map, but use math degrees (0 is east, degrees increase counter-clockwise), rather than compass degrees (0 is north, degrees increase clockwise) for orientation of transects. Compass decimal degrees can be converted to math degrees by subtracting them from 450; if the answer is greater than 360, subtract 360.

Many, but not all, maps are drawn to a scale, expressed as a ratio such as 1:10,000, meaning that 1 of any unit of measurement on the map corresponds exactly, or approximately, to 10,000 of that same unit on the ground. The scale statement may be taken as exact when the region mapped is small enough for the curvature of the Earth to be neglected, for example in a town planner's city map. Over larger regions where the curvature cannot be ignored we must use map projections from the curved surface of the Earth (sphere or ellipsoid) to the plane. The impossibility of flattening the sphere to the plane implies that no map projection can have constant scale: on most projections the best we can achieve is accurate scale on one or two lines (not necessarily straight) on the projection. Thus for map projections we must introduce the concept of point scale, which is a function of position, and strive to keep its variation within narrow bounds. Although the scale statement is nominal it is usually accurate enough for all but the most precise of measurements.

Large scale maps, say 1:10,000, cover relatively small regions in great detail and small scale maps, say 1:10,000,000, cover large regions such as nations, continents and the whole globe. The large/small terminology arose from the practice of writing scales as numerical fractions: 1/10,000 is larger than 1/10,000,000. There is no exact dividing line between large and small but 1/100,000 might well be considered as a medium scale. Examples of large scale maps are the 1:25,000 maps produced for hikers; on the other hand maps intended for motorists at 1:250,000 or 1:1,000,000 are small scale.

It is important to recognize that even the most accurate maps sacrifice a certain amount of accuracy in scale to deliver a greater visual usefulness to its user. For example, the width of roads and small streams are exaggerated when they are too narrow to be shown on the map at true scale; that is, on a printed map they would be narrower than could be perceived by the naked eye. The same applies to computer maps where the smallest unit is the pixel. A narrow stream say must be shown to have the width of a pixel even if at the map scale it would be a small fraction of the pixel width.

Some maps, called cartograms, have the scale deliberately distorted to reflect information other than land area or distance. For example, this map (at the right) of Europe has been distorted to show population distribution, while the rough shape of the continent is still discernible.

Another example of distorted scale is the famous London Underground map. The basic geographical structure is respected but the tube lines (and the River Thames) are smoothed to clarify the relationships between stations. Near the center of the map stations are spaced out more than near the edges of map.

Further inaccuracies may be deliberate. For example, cartographers may simply omit military installations or remove features solely in order to enhance the clarity of the map. For example, a road map may not show railroads, smaller waterways or other prominent non-road objects, and even if it does, it may show them less clearly (e.g. dashed or dotted lines/outlines) than the main roads. Known as decluttering, the practice makes the subject matter that the user is interested in easier to read, usually without sacrificing overall accuracy. Software-based maps often allow the user to toggle decluttering between ON, OFF and AUTO as needed. In AUTO the degree of decluttering is adjusted as the user changes the scale being displayed.

Maps of the world or large areas are often either 'political' or 'physical'. The most important purpose of the political map is to show territorial borders; the purpose of the physical is to show features of geography such as mountains, soil type or land use including infrastructure such as roads, railroads and buildings. Topographic maps show elevations and relief with contour lines or shading. Geological maps show not only the physical surface, but characteristics of the underlying rock, fault lines, and subsurface structures. Maps that depict the surface of the Earth also use a projection, a way of translating the three-dimensional real surface of the geoid to a two-dimensional picture. Perhaps the best-known world-map projection is the Mercator projection, originally designed as a form of nautical chart. Aeroplane pilots use aeronautical charts based on a Lambert conformal conic projection, in which a cone is laid over the section of the earth to be mapped. The cone intersects the sphere (the earth) at one or two parallels which are chosen as standard lines. This allows the pilots to plot a great-circle route approximation on a flat, two-dimensional chart.

From the last quarter of the 20th century, the indispensable tool of the cartographer has been the computer. Much of cartography, especially at the data-gathering survey level, has been subsumed by Geographic Information Systems (GIS). The functionality of maps has been greatly advanced by technology simplifying the superimposition of spatially located variables onto existing geographical maps. Having local information such as rainfall level, distribution of

wildlife, or demographic data integrated within the map allows more efficient analysis and better decision making. In the pre-electronic age such superimposition of data led Dr. John Snow to identify the location of an outbreak of cholera. Today, it is used by agencies of the human kind, as diverse as wildlife conservationists and militaries around the world.

Interactive, computerised maps are commercially available, allowing users to zoom in or zoom out (respectively meaning to increase or decrease the scale), sometimes by replacing one map with another of different scale, centered where possible on the same point. In-carglobal navigation satellite systems are computerised maps with route-planning and advice facilities which monitor the user's position with the help of satellites. From the computer scientist's point of view, zooming in entails one or a combination of:

1. replacing the map by a more detailed one
2. enlarging the same map without enlarging the pixels, hence showing more detail by removing less information compared to the less detailed version
3. enlarging the same map with the pixels enlarged (replaced by rectangles of pixels); no additional detail is shown, but, depending on the quality of one's vision, possibly more detail can be seen; if a computer display does not show adjacent pixels really separate, but overlapping instead (this does not apply for an LCD, but may apply for a cathode ray tube), then replacing a pixel by a rectangle of pixels does show more detail. A variation of this method is interpolation.

The various features shown on a map are represented by conventional signs or symbols. For example, colors can be used to indicate a classification of roads. Those signs are usually explained in the margin of the map, or on a separately published characteristic sheet.[1]

Some cartographers prefer to make the map cover practically the entire screen or sheet of paper, leaving no room "outside" the map for information about the map as a whole. These cartographers typically place such information in an otherwise "blank" region "inside" the map -- cartouche, map legend, title, compass rose, bar scale, etc. In particular, some maps contain smaller "sub-maps" in otherwise blank regions—often one at a much smaller scale showing the whole globe and where the whole map fits on that globe, and a few showing "regions of interest" at a larger scale in order to show details that wouldn't otherwise fit. Occasionally sub-maps use

the same scale as the large map—a few maps of the contiguous United States include a sub-map to the same scale for each of the two non-contiguous states.

To communicate spatial information effectively, features such as rivers, lakes, and cities need to be labeled. Over centuries cartographers have developed the art of placing names on even the densest of maps. Text placement or name placement can get mathematically very complex as the number of labels and map density increases. Therefore, text placement is time-consuming and labor-intensive, so cartographers and GIS users have developed automatic label placement to ease this process.

Diagrams such as schematic diagrams and Gantt charts and treemaps display logical relationships between items, and do not display spatial relationships at all.

Some maps, for example the London Underground map, are topological maps. Topological in nature, the distances are completely unimportant; only the connectivity is significant.

General-purpose maps provide many types of information on one map. Most atlas maps, wall maps, and road maps fall into this category. The following are some features that might be shown on a general-purpose maps: bodies of water, roads, railway lines, parks, elevations, towns and cities, political boundaries, latitude and longitude, national and provincial parks. These maps give a broad understanding of location and features of an area. You can gain an understanding of the type of landscape, the location of urban places, and the location of major transportation routes all at once.

Chapter 7

Thematic Maps

A thematic map is a type of map or chart especially designed to show a particular theme connected with a specific geographic area. These maps "can portray physical, social, political, cultural, economic, sociological, agricultural, or any other aspects of a city, state, region, nation, or continent".

A thematic map is a map that focuses on a specific theme or subject area, whereas in a general map the variety of phenomena—geological, geographical, political—regularly appear together. The contrast between them lies in the fact that thematic maps use the base data, such as coastlines, boundaries and places, only as points of reference for the phenomenon being mapped. General maps portray the base data, such as landforms, lines of transportation, settlements, and political boundaries, for their own sake.

Thematic maps emphasize spatial variation of one or a small number of geographic distributions. These distributions may be physical phenomena such as climate or human characteristics such as population density and health issues. Barbara Petchenik described the difference as "in place, about space." While general reference maps show where something is in space, thematic maps tell a story about that place (e.g., city map).

Thematic map are sometimes referred to as graphic essays that portray spatial variations and interrelationships of geographical distributions. Location, of course, is important to provide a reference base of where selected phenomena are occurring.

An important cartographic element preceding thematic mapping was the development of accurate base maps. Improvements in accuracy proceeded at a gradual pace, and even until the mid-17th century, general maps were usually of poor quality. Still, base maps around this time were good enough to display appropriate information, allowing for the first thematic maps to come into being.

One of the earliest thematic maps was a map entitled *Designatio orbis christiani* (1607) by Jodocus Hondius showing the dispersion of major religions, using map symbols in the French

edition of his *Atlas Minor* (1607). This was soon followed by a thematic globe (in the form of a six-gore map) showing the same subject, using Hondius' symbols, by Franciscus Haraeus, entitled: *Novus typus orbis ipsus globus, ex Analemmate Ptolomaei diductus* (1614)

An early contributor to thematic mapping in England was the English astronomer Edmond Halley (1656–1742).[2] His first significant cartographic contribution was a star chart of the constellation of the Southern Hemisphere, made during his stay on St. Helena and published in 1686. In that same year he also published his first terrestrial map in an article about trade winds, and this map is called the first meteorological chart. In 1701 he published the "New and Correct Chart Shewing the Variations of the Compass", see first image, the first chart to show lines of equal magnetic variation.

Another example of early thematic mapping comes from London physician John Snow. Though disease had been mapped thematically, Snow's cholera map in 1854 is the best known example of using thematic maps for analysis. Essentially, his technique and methodology anticipate principles of a geographic information system (GIS). Starting with an accurate base map of a London neighborhood which included streets and water pump locations, Snow mapped out the incidents of cholera death. The emerging pattern centered around one particular pump on Broad Street. At Snow's request, the handle of the pump was removed, and new cholera cases ceased almost at once. Further investigation of the area revealed the Broad Street pump was near a cesspit under the home of the outbreak's first cholera victim.

Another 19th century example of thematic maps, according to Friendly (2008), was the earliest known choropleth map in 1826 created by Charles Dupin. Based on this work Louis-Leger Gauthier (1815–1881) developed the population contour map, a map that shows the population density by contours or isolines.

USES OF THEMATIC MAPS

Thematic maps serve three primary purposes.

First, they provide specific information about particular locations.

Second, they provide general information about spatial patterns.

Third, they can be used to compare patterns on two or more maps.

Common examples are maps of demographic data such as population density. When designing a thematic map, cartographers must balance a number of factors in order to effectively represent the data. Besides spatial accuracy, and aesthetics, quirks of human visual perception and the presentation format must be taken into account.

In addition, the audience is of equal importance. Who will “read” the thematic map and for what purpose helps define how it should be designed. A political scientist might prefer having information mapped within clearly delineated county boundaries (choropleth maps). A state biologist could certainly benefit from county boundaries being on a map, but nature seldom falls into such smooth, man-made delineations. In which case, a dasymetric map charts the desired information underneath a transparent county boundary map for easy location referencing.

A thematic map is univariate if the non-location data is all of the same kind. Population density, cancer rates, and annual rainfall are three examples of univariate data.

Bivariate mapping shows the geographical distribution of two distinct sets of data. For example, a map showing both rainfall and cancer rates may be used to explore a possible correlation between the two phenomena.

More than two sets of data leads to multivariate mapping. For example, a single map might show population density in addition to annual rainfall and cancer rates.

BIVARIATE MAP

A bivariate map displays two variables on a single map by combining two different sets of graphic symbols or colors. Bivariate mapping is an important technique in cartography. Given a set of geographic features, a bivariate map displays two variables on a single map by combining two different sets of graphic symbols. It is a variation of simple choropleth map that portrays two separate phenomena simultaneously. The main objective of a bivariate map is to find a simple method for accurately and graphically illustrating the relationship between two spatially distributed variables. A bivariate map has potential to reveal relationships between variables more effectively than a side-by-side comparison of the corresponding univariate maps.

A bivariate map is recent graphical method which is intended to convey the spatial distribution of two variables and the geographical concentration of their relationship. A bivariate choropleth map uses color to solve a problem of representation in four dimensions; two spatial dimensions — longitude and latitude — and two statistical variables. Data classification and graphic representation of the classified data are two important processes involved in constructing a bivariate map. The number of classes should be possible to deal with by the reader. A rectangular legend box is divided into smaller boxes where each box represents a unique relationship of the variables.

In general, bivariate maps are one of the alternatives to the simple univariate choropleth maps, although they are sometimes extremely difficult to understand the distribution of a single variable. Because conventional bivariate maps use two arbitrarily assigned color schemes and generate random color combinations for overlapping sections and users have to refer to the arbitrary legend all the time. Therefore, a very prominent and clear legend is needed so that both the distribution of single variable and the relationship between the two variables could be shown on the bivariate map.

METHODS OF THEMATIC MAPPING

Cartographers use many methods to create thematic maps, but five techniques are especially noted.

CHOROPLETH

Choropleth mapping shows statistical data aggregated over predefined regions, such as counties or states, by coloring or shading these regions. For example, countries with higher rates of infant mortality might appear darker on a choropleth map. This technique assumes a relatively even distribution of the measured phenomenon within each region. Generally speaking, differences in hue are used to indicate qualitative differences, such as land use, while differences in saturation or lightness are used to indicate quantitative differences, such as population.

PROPORTIONAL SYMBOL

The proportional symbol technique uses symbols of different sizes to represent data associated with different areas or locations within the map. For example, a disc may be shown at the

location of each city in a map, with the area of the disc being proportional to the population of the city.

ISOPLETH

Isarithmic maps, also known as contour maps or isopleth maps depict smooth continuous phenomena such as precipitation or elevation. Each line-bounded area on this type of map represents a region with the same value. For example, on an elevation map, each elevation line indicates an area at the listed elevation. An Isarithmic map is a planimetric graphic representation of a 3-D surface. Isarithmic mapping requires 3-D thinking for surfaces that vary spatially.

DOT

A dot distribution map might be used to locate each occurrence of a phenomenon, as in Dr. Snow's map where each dot represented one death due to cholera. Where appropriate, a dot may indicate any number of entities, for example, one dot for every 100 voters.

DASYMETRIC

A dasymetric map is similar to a choropleth map, but one in which the regions are not predefined but chosen so that the distribution of the measured phenomenon within each region is relatively uniform. The boundaries may be much sharper than in an isarithmic map. For example, planning regulations may lead to adjacent regions in a dasymetric map of population density being internally homogeneous but at opposite extremes. These maps are more difficult to generate and less common than other types.

Chapter 8

Topographic Maps

In modern mapping, a topographic map is a type of map characterized by large-scale detail and quantitative representation of relief, usually using contour lines but, historically, using a variety of methods. Traditional definitions require a topographic map to show both natural and man-made features. A topographic map is typically published as a map series, made up of two or more map sheets that combine to form the whole map. A contour line is a combination of two line segments that connect but do not intersect; these represent elevation on a topographic map.

The Canadian Centre for Topographic Information provides this definition:

A topographic map is a detailed and accurate graphic representation of cultural and natural features on the ground.

Other authors define topographic maps by contrasting them with another type of map; they are distinguished from smaller-scale "chorographic maps" that cover large regions, "planimetric maps" that do not show elevations, and "thematic maps" that focus on specific topics.

However, in the vernacular and day to day world, the representation of relief (contours) is popularly held to define the genre, such that even small-scale maps showing relief are commonly (and erroneously, in the technical sense) called "topographic".

The study or discipline of topography, while interested in relief, is actually a much broader field of study which takes into account all natural and man made features of terrain.

Topographic maps are based on topographical surveys. Performed at large scales, these surveys are called topographical in the old sense of topography, showing a variety of elevations and landforms. This is in contrast to older cadastral surveys, which primarily show property and governmental boundaries. The first multi-sheet topographic map series of an entire country, the *Carte géométrique de la France*, was completed in 1789. The Great Trigonometric Survey of India, started by the East India Company in 1802, then taken over by the British Raj after 1857 was notable as a successful effort on a larger scale and for accurately determining heights of Himalayan peaks from viewpoints over one hundred miles distant.



Global indexing system first developed for International Map of the World

Topographic surveys were prepared by the military to assist in planning for battle and for defensive emplacements (thus the name and history of the United Kingdom's Ordnance Survey). As such, elevation information was of vital importance.

As they evolved, topographic map series became a national resource in modern nations in planning infrastructure and resource exploitation. In the United States, the national map-making function which had been shared by both the Army Corps of Engineers and the Department of the Interior migrated to the newly created United States Geological Survey in 1879, where it has remained since.

1913 saw the beginning of the International Map of the World initiative endeavoring to map all of Earth's significant land areas at 1:1 million scale on about one thousand sheets covering four degrees latitude by six or more degrees longitude. Excluding boundaries, each sheet was 44 cm high and (depending on latitude) up to 66 cm wide. Although the project eventually foundered, it left an indexing system that remains in use.

By the 1980s, centralized printing of standardized topographic maps began to be eroded by databases of coordinates that could be used on computers by moderately skilled end users to view or print maps with arbitrary contents, coverage and scale. For example the Federal government of the United States' TIGER initiative compiled interlinked databases of federal, state and local political borders and census enumeration areas, and of roadways, railroads, and water features with support for locating street addresses within street segments. TIGER was developed in the 1980s and used in the 1990 and subsequent decennial censuses. Digital

elevation models (DEM) were also compiled, initially from topographic maps and stereographic interpretation of aerial photographs and then from satellite photography and radar data. Since all these were government projects funded with taxes and not classified for national security reasons, the datasets were in the public domain and freely usable without fees or licensing.

TIGER and DEM datasets greatly facilitated Geographic information systems and made the Global Positioning System much more useful by providing context around locations given by the technology as coordinates. Initial applications were mostly professionalized forms such as innovative surveying instruments and agency-level GIS systems tended by experts. By the mid-1990s, increasingly user-friendly resources such as online mapping in two and three dimensions, integration of GPS with mobile phones and automotive navigation systems appeared. As of 2011, the future of standardized, centrally printed topographical maps is left somewhat in doubt.

USES



Curvimeter used to calculate length of a curve

Topographic maps have multiple uses in the present day: any type of geographic planning or large-scale architecture; earth sciences and many other geographic disciplines; mining and other earth-based endeavours; civil engineering and recreational uses such as hiking and orienteering.

Map conventions

The various features shown on the map are represented by conventional signs or symbols. For example, colors can be used to indicate a classification of roads. These signs are usually explained in the margin of the map, or on a separately published characteristic sheet.[14]

Topographic maps are also commonly called contour maps or topo maps. In the United States, where the primary national series is organized by a strict 7.5 minute grid, they are often called topo quads or quadrangles.

Topographic maps conventionally show topography, or land contours, by means of contour lines. Contour lines are curves that connect contiguous points of the same altitude (isohypse). In other words, every point on the marked line of 100 m elevation is 100 m above mean sea level.

These maps usually show not only the contours, but also any significant streams or other bodies of water, forest cover, built-up areas or individual buildings (depending on scale), and other features and points of interest.

Today, topographic maps are prepared using photogrammetric interpretation of aerial photography, LIDAR and other Remote sensing techniques. Older topographic maps were prepared using traditional surveying instruments.

Although virtually the entire terrestrial surface of Earth has been mapped at scale 1:1,000,000, medium and large-scale mapping has been accomplished intensively in some countries and much less in others. Nevertheless national mapping programs listed below are only a partial selection. Several commercial vendors supply international topographic map series.

Australia

The NMIG (National Mapping Information Group) of Geoscience Australia is the Australian Government's national mapping agency. It provides topographic maps and data to meet the needs of the sustainable development of the nation. The Office of Spatial Data Management provides an online free map service MapConnect. These topographic maps of scales 1:250,000 and 1:100,000 are available in printed form from the Sales Centre. 1:50,000 and 1:25,000 maps are

produced in conjunction with the Department of Defence.

Austria

Austrian Maps (German: Österreichische Karte (ÖK)) is the government agency producing maps of Austria, which are distributed by Bundesamt für Eich- und Vermessungswesen (BEV) in Vienna. The maps are published at scales 1:25,000 1:50,000 1:200,000 and 1:500,000. Maps can also be viewed online.

Canada

The Centre for Topographic Information produces topographic maps of Canada at scales of 1:50,000 and 1:250,000. They are known as the National Topographic System (NTS). A government proposal to discontinue publishing of all hardcopy or paper topographic maps in favor of digital-only mapping data was shelved in 2006 after intense public opposition

China

The State Bureau of Surveying and Cartography compiles topographic maps at 1:25,000 and 1:50,000 scales. It is reported that these maps are accurate and attractively printed in seven colors, and that successive editions show progressive improvement in accuracy.

These large-scale maps are the basis for maps at smaller scales. Maps at scales 1:4,000,000 or smaller are exported by Cartographic Publishing House, Beijing while larger-scale maps are restricted as state secrets. China's topographic maps follow the international system of subdivision with 1:100,000 maps spanning 30 minutes longitude by 20 minutes latitude.

Colombia

The Geographic Institute Agustín Codazzi is the government entity responsible for producing and distributing topographic maps of Colombia in 1:500,000 and 1:100,000 scales. These and several other Geographic information services can be accessed using the Instituto Geográfico Agustín Codazzi website in Spanish.

Denmark

The National Survey and Cadastre of Denmark is responsible for producing topographic and nautical geodata of Denmark, Greenland and the Faroe Islands

Finland

The National Land Survey of Finland produces the Topographic Database (accuracy 1:5000-1:10 000) and publishes topographic maps of Finland at 1:25,000 and 1:50,000. In addition topographic maps can be viewed by using a free map service MapSite.

France

The Institut Géographique National (IGN) produces topographic maps of France at 1:25,000 and 1:50,000. In addition, topographic maps are freely accessible online, through the Géoportail website.

Germany

In principle, each federal state (Bundesland) is in charge of producing the official topographic maps. In fact, the maps between 1:5,000 and 1:100,000 are produced and published by the land surveying offices of each federal state, the maps between 1:200,000 and 1:1,000,000 by a federal office – the Bundesamt für Kartographie und Geodäsie (BKG) in Frankfurt am Main.

Greece

Topographic maps for general use are available at 1:50,000 and 1:100,000 from the Hellenic Military Geographical Service (HMGS) They use a national projection system called EGSA'87, which is a Transverse Mercatorial Projection mapping Greece in one zone. A few areas are also available at 1:25,000. Some private firms sell topographic maps of national parks based on HMGS topography.

India

The Survey of India is responsible for all topographic control, surveys and mapping of India.

Japan

The Geographical Survey Institute of Japan is responsible for base mapping of Japan. Standard map scales are 1:25,000, 1:50,000, 1:200,000 and 1:500,000.

New Zealand

Land Information New Zealand is the government agency responsible for providing up-to-date topographic mapping. LINZ topographic maps cover all of New Zealand, offshore islands, some Pacific Islands and the Ross Sea Region. The standard issue NZTopo map series was published September 2009 at 1:50,000 (NZTopo50), and 1:250,000 (NZTopo250). Vector data from the New Zealand Topographic Database (NZTopo) is also available.

Pakistan

The responsibility for topographic mapping and aerial photography lies with the Surveyor General of Pakistan [SGP]. Established in 1947, the Survey of Pakistan (SOP) is based in Rawalpindi with a number of regional offices distributed at urban centers throughout Pakistan. SGP is a civil organization which, for security reasons, is headed by a Surveyor General and works under the strict control of Army General Headquarters (GHQ). Colonel C.A.K. Innes-Wilson, a Royal Engineers officer who joined the Survey of India which mapped the subcontinent, was the first Surveyor General of Pakistan.

All departments which require topographic maps make their request to SGP and many are permanently registered with it for mapping and aerial photographs procurement. The SOP performs these functions under the auspices of the Ministry of Defence (MOD). Organisationally, the SOP is overseen by the Surveyor General (SG) who is a direct military appointee and a senior uniformed officer. The SG reports directly to the Secretary of Defence. Under the SG are two Deputy SG's (I and II) who manage the operational departments of the agency and a Senior Technical Advisor. These departments are divided into Regional Directorates for Topographic Mapping including the Northern region centred in Peshawar, Eastern region (Lahore), Western region (Quetta) and finally, the Southern region in Karachi. Responsibility for fields surveys and the maintenance/update of topographic maps are subdivided according to these geographic areas.

Portugal

The Army's Geographical Institute - Instituto Geográfico do Exército - produces 1.25,000, 1:500,000 maps for public sale, as well as lots of geographical services.

Russia

Detailed, accurate topographic maps have long been a military priority. They are currently produced by the Military-topographic service of armed forces of the Russian Federation (Russian: Военно-топографическая служба Вооружённых сил Российской Федерации or BTC ВС). Military topographic mapping departments held other titles in the Russian Empire since 1793 and in the Soviet Union where these maps also came to be used for internal control and economic development.

When Germany invaded in 1941, detailed maps from the USSR's western borders to the Volga River became an urgent task, accomplished in less than one year. After the war years the entire Soviet Union was mapped at scales down to 1:25,000—even 1:10,000 for the agriculturally productive fraction. The rest of the world except Antarctica is believed to have been mapped at scales down to 1:200,000, with regions of special interest down to 1:50,000 and many urban areas to 1:10,000. In all there may have been over one million map sheets of high quality and detail. Soviet maps were also notable for their consistent global indexing system. These advantages held for Soviet military maps of other countries, although there were some errors due to faulty intelligence.

Soviet maps for domestic civilian purposes were often of lower quality. From 1919 to 1967 they were produced by Head geodesic administration (Russian: Высшее геодезическое управление or ВГУ), then by Chief administration of geodesy and cartography (Russian: Главное управление геодезии и картографии or ГУГК). Now (June 2011) civilian maps are produced by the Federal agency for geodesy and cartography (Russian: Федеральное агентство геодезии и картографии or Роскартография). Soviet military maps were state secrets. After the 1991 breakup of the Soviet Union, many maps leaked into the public domain] and are available for download.[48] Map scales 1:100.000 - 1:500.000 can be viewed online.

Spain

The Instituto Geográfico Nacional (IGN) is responsible for the official topographic maps. It does use six scales that cover all the Spanish territory: 1:25,000, 1:50,000, 1:200,000, 1:500,000, 1:1,000,000 and 1:2,000,000. The most common scale is the first one, which utilizes the UTM system.

South Africa

The Chief Directorate: National Geo-spatial Information (CD:NGI) produces three topographic map series, each covering the whole country, at scales 1:50 000, 1:250 000, and 1:500 000.

Switzerland

Swisstopo (the Federal Office of Topography) produces topographic maps of Switzerland at seven different scales.

United Kingdom

The Ordnance Survey (OS) produces topographic map series covering the United Kingdom at 1:25,000 and 1:50,000 scales. The 1:25,000 scale is known as the "Explorer" series, and include an "OL" (Outdoor Leisure) sub-series for areas of special interest to hikers and walkers. It replaced the "Pathfinder" series, which was less colourful and covered a smaller area on each map. The 1:50,000 scale is known as the "Landranger" and carries a distinctive pink cover. More detailed mapping as fine as 1:10000 cover some parts of the country. The 1:25K and 1:50K metric scales are easily coordinated with standard romer scales on currently available compasses and plotting tools. The Ordnance Survey maintains a mapping database from which they can print specialist maps at virtually any scale.

Ordnance Survey National Grid divides the U.K. into cells 500 km. and 100 km.square on a Transverse Mercator grid aligned true North-South along the 2°W meridian. OS map products are based on this grid.

United States

The United States Geological Survey (USGS), a civilian federal agency, produces several national series of topographic maps which vary in scale and extent, with some wide gaps in coverage, notably the complete absence of 1:50,000 scale topographic maps or their equivalent.

The largest (both in terms of scale and quantity) and best-known topographic series is the 7.5-minute or 1:24,000 quadrangle. This scale is unique to the United States, where nearly every other developed nation has introduced a metric 1:25,000 or 1:50,000 large scale topo map. The USGS also publishes 1:100,000 maps covering 30 minutes latitude by one degree longitude, 1:250,000 covering one by two degrees, and state maps at 1:500,000 with California, Michigan and Montana needing two sheets while Texas has four. Alaska is mapped on a single sheet, at scales ranging from 1:1,584,000 to 1:12,000,000

Recent USGS digital US Topo 1:24,000 topo maps based on the National Map omit several important geographic details that were featured in the original USGS topographic map series (1945-1992). Examples of omitted details and features include power transmission lines, telephone lines, railroads, recreational trails, pipelines, survey marks, and buildings. For many of these feature classes, the USGS is working with other agencies to develop data or adapt existing data on missing details that will be included in The National Map and to US Topo. In other areas USGS digital map revisions may omit geographic features such as ruins, mine locations, springs, wells, and even trails in an effort to protect natural resources and the public at large, or because such features are not present in any public domain database.

Chapter 9

Cad

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

Computer-aided design is used in many fields. Its use in designing electronic systems is known as Electronic Design Automation, or EDA. In mechanical design it is known as Mechanical Design Automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software.

CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.

CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC Digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

The design of geometric models for object shapes, in particular, is occasionally called computer-aided geometric design (CAGD).

While the goal of automated CAD systems is to increase efficiency, they are not necessarily the best way to allow newcomers to understand the geometrical principles of Solid Modeling. For this, scripting languages such as PLaSM (Programming Language of Solid Modeling) are more suitable.[citation needed]

Beginning in the 1980s computer-aided design programs reduced the need of draftsmen significantly, especially in small to mid-sized companies. Their affordability and ability to run on personal computers also allowed engineers to do their own drafting and analytic work, eliminating the need for entire departments. In today's world, many students in universities do not learn manual drafting techniques because they are not required to do so. The days of hand drawing for final drawings are virtually over. Universities no longer require the use of protractors and compasses to create drawings, instead there are several classes that focus on the use of CAD software.

Current computer-aided design software packages range from 2D vector-based drafting systems to 3D solid and surface modelers. Modern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out. Some CAD software is capable of dynamic mathematical modeling, in which case it may be marketed as CADD.

CAD is used in the design of tools and machinery and in the drafting and design of all types of buildings, from small residential types (houses) to the largest commercial and industrial structures (hospitals and factories).

CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. It can also be used to design objects. Furthermore many CAD applications now offer advanced rendering and animation capabilities so engineers can better visualize their product designs.4D BIM is a type of virtual construction engineering simulation incorporating time or schedule related information for project management.

CAD has become an especially important technology within the scope of computer-aided technologies, with benefits such as lower product development costs and a greatly shortened design cycle. CAD enables designers to layout and develop work on screen, print it out and save it for future editing, saving time on their drawings.

Computer-aided design is one of the many tools used by engineers and designers and is used in many ways depending on the profession of the user and the type of software in question.

CAD is one part of the whole Digital Product Development (DPD) activity within the Product Lifecycle Management (PLM) processes, and as such is used together with other tools, which are either integrated modules or stand-alone products, such as:

Computer-aided engineering (CAE) and Finite element analysis (FEA)

Computer-aided manufacturing (CAM) including instructions to Computer Numerical Control (CNC) machines

Document management and revision control using Product Data Management (PDM).

CAD is also used for the accurate creation of photo simulations that are often required in the preparation of Environmental Impact Reports, in which computer-aided designs of intended buildings are superimposed into photographs of existing environments to represent what that locale will be like were the proposed facilities allowed to be built. Potential blockage of view corridors and shadow studies are also frequently analyzed through the use of CAD.

CAD has been proven to be useful to engineers as well. Using four properties which are history, features, parameterization, and high level constraints. The construction history can be used to look back into the model's personal features and work on the single area rather than the whole model. Parameters and constraints can be used to determine the size, shape, and other properties of the different modeling elements. The features in the CAD system can be used for the variety of tools for measurement such as tensile strength, yield strength, electrical or electro-magnetic properties. Also its stress, strain, timing or how the element gets affected in certain temperatures, etc.

There are several different types of CAD, each requiring the operator to think differently about how to use them and design their virtual components in a different manner for each.

There are many producers of the lower-end 2D systems, including a number of free and open source programs. These provide an approach to the drawing process without all the fuss over scale and placement on the drawing sheet that accompanied hand drafting, since these can be adjusted as required during the creation of the final draft.

3D wireframe is basically an extension of 2D drafting (not often used today). Each line has to be manually inserted into the drawing. The final product has no mass properties associated with it and cannot have features directly added to it, such as holes. The operator approaches these in a similar fashion to the 2D systems, although many 3D systems allow using the wireframe model to make the final engineering drawing views.

3D "dumb" solids are created in a way analogous to manipulations of real world objects (not often used today). Basic three-dimensional geometric forms (prisms, cylinders, spheres, and so on) have solid volumes added or subtracted from them, as if assembling or cutting real-world objects. Two-dimensional projected views can easily be generated from the models. Basic 3D solids don't usually include tools to easily allow motion of components, set limits to their motion, or identify interference between components.

Solid Modeling There are two types of solid modeling

1). 3D parametric solid modeling allows the operator to use what is referred to as "design intent". The objects and features created are modifiable. Any future modifications will be made by changing how the original part was created. If a feature was intended to be located from the center of the part, the operator should locate it from the center of the model. The feature could be located using any geometric object already available in the part, but this random placement would defeat the design intent. If the operator designs the part as it functions the parametric modeler is able to make changes to the part while maintaining designed-in relationships.

2). Explicit Modellers or Direct 3D CAD Modelers provide the ability to edit geometry without a history tree. With direct modeling once a sketch is used to create geometry the sketch is incorporated into the new geometry and the designer just modifies the geometry without needing

the original sketch. As with Parametric modeling, Direct modeling has the ability to include relationships between selected geometry (e.g., tangency, concentricity).

Top end systems offer the capabilities to incorporate more organic, aesthetics and ergonomic features into designs. Freeform surface modeling is often combined with solids to allow the designer to create products that fit the human form and visual requirements as well as they interface with the machine.

Originally software for Computer-Aided Design systems was developed with computer languages such as Fortran, ALGOL but with the advancement of object-oriented programming methods this has radically changed. Typical modern parametric feature based modeler and freeform surface systems are built around a number of key C modules with their own APIs. A CAD system can be seen as built up from the interaction of a graphical user interface (GUI) with NURBS geometry and/or boundary representation (B-rep) data via a geometric modeling kernel. A geometry constraint engine may also be employed to manage the associative relationships between geometry, such as wireframe geometry in a sketch or components in an assembly.

Unexpected capabilities of these associative relationships have led to a new form of prototyping called digital prototyping. In contrast to physical prototypes, which entail manufacturing time in the design. That said, CAD models can be generated by a computer after the physical prototype has been scanned using an industrial CT scanning machine. Depending on the nature of the business, digital or physical prototypes can be initially chosen according to specific needs.

Today, CAD systems exist for all the major platforms (Windows, Linux, UNIX and Mac OS X); some packages even support multiple platforms.

Right now, no special hardware is required for most CAD software. However, some CAD systems can do graphically and computationally intensive tasks, so a modern graphics card, high speed (and possibly multiple) CPUs and large amounts of RAM may be recommended.

The human-machine interface is generally via a computer mouse but can also be via a pen and digitizing graphics tablet. Manipulation of the view of the model on the screen is also sometimes done with the use of a Spacemouse/SpaceBall. Some systems also support stereoscopic glasses for viewing the 3D model. Technologies which in the past were limited to larger installations or

specialist applications have become available to a wide group of users. These include the CAVE or HMD's and interactive devices like motion-sensing technology

Designers have long used computers for their calculations. Digital computers were used in power system analysis or optimization as early as proto-"Whirlwind" in 1949. Circuit design theory, or power network methodology would be algebraic, symbolic, and often Vector based. Examples of problems being solved in the mid-1940s to 50s include, Servo motors controlled by generated pulse (1949), The digital computer with built-in compute operations automatic co-ordinate transform to compute radar related vectors (1951) and the essentially graphic mathematical process of forming a shape with a digital machine tool (1952) were accomplished with the use of computer software. The man credited with coining the term CAD, Douglas T. Ross stated "As soon as I saw the interactive display equipment, [being used by radar operators 1953] I said "Gee, that's just what we need". The designers of these very early computers built utility programs so that programmers could debug programs using flow charts on a display scope with logical switches that could be opened and closed during the debugging session. They found that they could create electronic symbols and geometric figures to be used to create simple circuit diagrams and flow charts.[16] They made the pleasant discovery that an object once drawn could be reproduced at will, its orientation, Linkage [flux, mechanical, lexical scoping] or scale changed. This suggested numerous possibilities to them. It took ten years of interdisciplinary development work before SKETCHPAD sitting on evolving math libraries emerged from MIT's labs. Additional developments were carried out in the 1960s within the aircraft, automotive, industrial control and electronics industries in the area of 3D surface construction, NC programming and design analysis, most of it independent of one another and often not publicly published until much later. Some of the mathematical description work on curves was developed in the early 1940s by Robert Isaac Newton from Pawtucket, Rhode Island. Robert A. Heinlein in his 1957 novel *The Door into Summer* suggested the possibility of a robotic Drafting Dan. However, probably the most important work on polynomial curves and sculptured surface was done by Pierre Bézier (Renault), Paul de Casteljau (Citroen), Steven Anson Coons (MIT, Ford), James Ferguson (Boeing), Carl de Boor (GM), Birkhoff (GM) and Garibedian (GM) in the 1960s and W. Gordon (GM) and R. Riesenfeld in the 1970s.

It is argued that a turning point was the development of the SKETCHPAD system at MIT by Ivan Sutherland (who later created a graphics technology company with Dr. David Evans). The distinctive feature of SKETCHPAD was that it allowed the designer to interact with his computer graphically: the design can be fed into the computer by drawing on a CRT monitor with a light pen. Effectively, it was a prototype of graphical user interface, an indispensable feature of modern CAD. Sutherland presented his paper Sketchpad: A Man-Machine Graphical Communication System in 1963 at a Joint Computer Conference having worked on it as his PhD thesis paper for a few years. Quoting, "For drawings where motion of the drawing, or analysis of a drawn problem is of value to the user, Sketchpad excels. For highly repetitive drawings or drawings where accuracy is required, Sketchpad is sufficiently faster than conventional techniques to be worthwhile. For drawings which merely communicate with shops, it is probably better to use conventional paper and pencil." Over time efforts would be directed toward the goal of having the designers drawings communicate not just with shops but with the shop tool itself. This goal would be a long time arriving.

The first commercial applications of CAD were in large companies in the automotive and aerospace industries, as well as in electronics. Only large corporations could afford the computers capable of performing the calculations. Notable company projects were at GM (Dr. Patrick J. Hanratty) with DAC-1 (Design Augmented by Computer) 1964; Lockheed projects; Bell GRAPHIC 1 and at Renault (Bézier) – UNISURF 1971 car body design and tooling.

One of the most influential events in the development of CAD was the founding of MCS (Manufacturing and Consulting Services Inc.) in 1971 by Dr. P. J. Hanratty, who wrote the system ADAM (Automated Drafting And Machining) but more importantly supplied code to companies such as McDonnell Douglas (Unigraphics), Computervision (CADDs), Calma, Gerber, Autotrol and Control Data.

As computers became more affordable, the application areas have gradually expanded. The development of CAD software for personal desktop computers was the impetus for almost universal application in all areas of construction.

Other key points in the 1960s and 1970s would be the foundation of CAD systems United Computing, Intergraph, IBM, Intergraph IGDS in 1974 (which led to Bentley Systems MicroStation in 1984).

CAD implementations have evolved dramatically since then. Initially, with 3D in the 1970s, it was typically limited to producing drawings similar to hand-drafted drawings. Advances in programming and computer hardware, notably solid modeling in the 1980s, have allowed more versatile applications of computers in design activities.

Key products for 1981 were the solid modelling packages -Romulus (ShapeData) and Uni-Solid (Unigraphics) based on PADL-2 and the release of the surface modeler CATIA (Dassault Systemes). Autodesk was founded 1982 by John Walker, which led to the 2D system AutoCAD. The next milestone was the release of Pro/ENGINEER in 1988, which heralded greater usage of feature-based modeling methods and parametric linking of the parameters of features. Also of importance to the development of CAD was the development of the B-rep solid modeling kernels (engines for manipulating geometrically and topologically consistent 3D objects) Parasolid (ShapeData) and ACIS (Spatial Technology Inc.) at the end of the 1980s and beginning of the 1990s, both inspired by the work of Ian Braid. This led to the release of mid-range packages such as SolidWorks and TriSpective (later known as IronCAD) in 1995, Solid Edge (then Intergraph) in 1996 and Autodesk Inventor in 1999.

Chapter 10

Cartogram

A cartogram is a map in which some thematic mapping variable – such as travel time, population, or Gross National Product – is substituted for land area or distance. The geometry or space of the map is distorted in order to convey the information of this alternate variable. There are two main types of cartograms: area and distance cartograms. Cartograms have a fairly long history, with examples from the mid-1800s.

An area cartogram is sometimes referred to as a value-by-area map or an isodemographic map, the latter particularly for a population cartogram, which illustrates the relative sizes of the populations of the countries of the world by scaling the area of each country in proportion to its population; the shape and relative location of each country is retained to as large an extent as possible, but inevitably a large amount of distortion results. Other synonyms in use are anamorphic map, density-equalizing map and Gastner map.

Area cartograms may be contiguous or noncontiguous. The area cartograms shown on this page are all contiguous, while a good example of a noncontiguous cartogram was published in The New York Times. The online resource , provided by Mapping Worlds, creates discontinuous cartograms for different geographies (United States, Japan and World at this time) interactively, allowing users to quickly compare various characteristics. This method of cartogram creation is sometimes referred to as the projector method or scaled-down regions.

Cartograms may be classified also by the properties of shape and topology preservation. Classical area cartograms (shown on this page) are typically distorting the shape of spatial units to some degree, but they are strict at preserving correct neighborhood relationships between them. Scaled-down cartograms (from the NY Times example) are strictly shape-preserving. Another branch of cartograms introduced by Dorling, replaces actual shapes with circles scaled according to the mapped feature. Circles are distributed to resemble the original topology. Demers cartogram is a variation of Dorling cartogram, but it uses rectangles instead of circles, and attempts to retain visual cues at the expense of minimum distance. Schematic maps based on

quad trees can be seen as non shape-preserving cartograms with some degree of neighborhood preservation.

A collection of about 700 contiguous area cartograms is available at Worldmapper, a collaborative team of researchers at the Universities of Sheffield and Michigan.

One of the first cartographers to generate cartograms with the aid of computer visualization was Waldo Tobler of UC Santa Barbara in the 1960s. Prior to Tobler's work, cartograms were created by hand (as they occasionally still are). The National Center for Geographic Information and Analysis located on the UCSB campus maintains an online Cartogram Central with resources regarding cartograms.

A number of software packages generate cartograms. Most of the available cartogram generation tools work in conjunction with other GIS software tools as add-ons or independently produce cartographic outputs from GIS data formatted to work with commonly used GIS products. Examples of cartogram software include ScapeToad, Cart, and the Cartogram Processing Tool (an ArcScript for ESRI's ArcGIS)

CHOROPLETH MAP

A choropleth map , ("area/region" + "multitude") is a thematic map in which areas are shaded or patterned in proportion to the measurement of the statistical variable being displayed on the map, such as population density or per-capita income.

The choropleth map provides an easy way to visualize how a measurement varies across a geographic area or it shows the level of variability within a region.

A special type of choropleth map is a prism map, a three-dimensional map in which a given region's height on the map is proportional to the statistical variable's value for that region.

The earliest known choropleth map was created in 1826 by Baron Pierre Charles Dupin. The term "choropleth map" was introduced 1938 by the geographer John Kirtland Wright in "Problems in Population Mapping".

Choropleth maps are based on statistical data aggregated over previously defined regions (e.g., counties), in contrast to area-class and isarithmic maps, in which region boundaries are defined

by data patterns. Thus, where defined regions are important to a discussion, as in an election map divided by electoral regions, choropleths are preferred.

Where real-world patterns may not conform to the regions discussed, issues such as the ecological fallacy and the modifiable areal unit problem (MAUP) can lead to major misinterpretations, and other techniques are preferable. Choropleth maps are frequently used in inappropriate applications due to the abundance of choropleth data and the ease of design using Geographic Information Systems.



Incorrect (population, left) and correct (population density, right) application of a choropleth to data for Boston, Massachusetts

The dasymetric technique can be thought of as a compromise approach in many situations. Broadly speaking choropleths represent two types of data: Spatially Extensive or Spatially Intensive.

- Spatially Extensive data are things like populations. The population of the UK might be 60 million, but it would not be accurate to arbitrarily cut the UK into two halves of equal area and say that the population of each half of the UK is 30 million.
- Spatially Intensive data are things like rates, densities and proportions, which can be thought of conceptually as field data that is averaged over an area. Though the UK's 60 million inhabitants occupy an area of about 240,000 km², and the population density is therefore about 250/km², arbitrary halves of equal area would not also both have the same population density.

Another common error in choropleths is the use of raw data values to represent magnitude rather than normalized values to produce a map of densities. This is problematic because the eye naturally integrates over areas of the same color, giving undue prominence to larger polygons of moderate magnitude and minimizing the significance of smaller polygons with high magnitudes. Compare the circled features in the maps at right.

When mapping quantitative data, a specific color progression should be used to depict the data properly. There are several different types of color progressions used by cartographers. The following are described in detail in Robinson et al. (1995)

Single hue progression

Single-hue progressions fade from a dark shade of the chosen color to a very light or white shade of relatively the same hue. This is a common method used to map magnitude. The darkest hue represents the greatest number in the data set and the lightest shade representing the least number.

Two variables may be shown through the use of two overprinted single color scales. The hues typically used are from red to white for the first data set and blue to white for the second, they are then overprinted to produce varying hues. These type of maps show the magnitude of the values in relation to each other.

Bi-polar color progression

Bi-polar progressions are normally used with two opposite hues to show a change in value from negative to positive or on either side of some either central tendency, such as the mean of the variable being mapped or other significant value like room temperature. For example a typical progression when mapping temperatures is from dark blue (for cold) to dark red (for hot) with white in the middle. When one extreme can be considered better than the other (as in this map of

life expectancy) then it is common to denote the poor alternative with shades of red, and the good alternative with green.

Complementary hue progressions are a type of bi-polar progression. This can be done with any of the complementary colors and will fade from each of the darker end point hues into a gray shade representing the middle. An example would be using blue and yellow as the two end points.

Blended hue color progression

Blended hue progressions use related hues to blend together the two end point hues. This type of color progression is typically used to show elevation changes. For example from yellow through orange to brown.

Partial spectral color progression

Partial spectral hue progressions are used to map mixtures of two distinct sets of data. This type of hue progression will blend two adjacent opponent hues and show the magnitude of the mixing data classes.

Full-spectral color progression

Full spectral progression contains hues from blue through red. This is common on relief maps and modern weather maps. This type of progression is not recommended under other circumstances because certain color connotations can confuse the map user.

Value progression

Value progression maps are monochromatic. Although any color may be used, the archetype is from black to white with intervening shades of gray that represent magnitude. According to Robinson et al. (1995), this is the best way to portray a magnitude message to the map audience. It is clearly understood by the user and easy to produce in print.

When using any of these methods there are two important principles: first is that darker colors are perceived as being higher in magnitude and second is that while there are millions of color variations the human eye is limited to how many colors it can easily distinguish. Generally five to seven color categories are recommended. The map user should be able to easily identify the implied magnitude of the hue and match it with the legend.

Additional considerations include color blindness and various reproduction techniques. For example, the red–green bi-polar progression described in the section above is likely to cause problems for dichromats. A related issue is that color scales which rely primarily on hue with insufficient variation in saturation or intensity may be compromised if reproduced with a black and white device; if a map is legible in black and white, then a prospective user's perception of color is irrelevant.

Color can greatly enhance the communication between the cartographer and their audience but poor color choice can result in a map that is neither effective nor appealing to the map user; sometimes simpler is better.

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