Maps for the Future:
Children, Education and Internet
Joint ICA Symposium

Cartography in Education

THE ROLE OF OUTPUT DEVICES IN THE HIGHER EDUCATION OF CARTOGRAPHY

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Abstract: The rapid development of information technology affected cartography considerably in the last four decades of the 20th century. Traditional offset printing methods were developed neither by and nor for cartography. In the cartographic curriculum, however, these techniques were taught to let cartographers control/evaluate the final phase of map making. The first digital output device used by cartographers (and also by students in the higher education) was the pen plotter. Other type of early computer printers (line printers and dot matrix printers) were only used at large firms, but their output was of very poor quality for cartographic purpose. Colour dot matrix printers were able to print colour maps, but both the speed and quality was insufficient. This technology was soon replaced by inkjet printing, which is still the most common and most affordable method (even in large format).

In higher education curricula, the reproduction process was taught as an independent subject or a part of other related subjects. Cartographers should know the complete technical process to be sure that the maps will be reproduced as they were planned. In the second phase, when the digital output devices became wide-spread and higher education institutions could afford these devices, the course on map reproduction was completed with digital methods, and the necessary theoretical information about the process was also added. In the third phase, when the output device became easily available for even home users, the traditional offset printing method has seemingly lost its importance, and the students became rather interested in the digital printing methods. Nowadays, the most important output devices in cartography are the screen of the computer, mobile phone, and PDA, which again made us introduce changes in the curriculum.

Introduction

The first independent cartographic courses were established at the Moscow State University of Geodesy and Cartography (MIIGAiK) in 1923. Although there were several major institutions where cartography was taught (e.g. in Zurich and Vienna), these and other Western and Central European universities and high schools needed a longer time to establish their independent cartography programmes.

Looking at the curricula of the first cartography programmes, the difference between the early and modern structures is striking. Much fewer courses are offered now in cartography than 30-40 years ago: most of the courses are converted to courses named as GIS, geoinformatics or geomatics. The subject on reproduction has disappeared from the courses, although this subject used to be an important part of cartography courses (Salichtchev, 1979).

Traditional reproduction methods as an output "device"

The reproduction methods were always very important in map making. We can not simply consider these techniques scientific, because they are mostly artistic or industrial methods. We do not have reproduction techniques directly developed for cartography, but cartography selected the best available methods that fitted the needs.

The printing methods of the first centuries after Gutenberg are less important for cartographers. Most printing technology was based on letterpress, namely, the printing of images that were projected above the nonprinting areas.

The first method worth mentioning is lithography. In 1798, Alois Senefelder made a discovery of profound significance in the history of artists' prints and later of commercial printing too. He had been attempting for some while to print from limestone. What he came to realize is that the antipathy between grease and water can be used as a basis for printing. He found that an image, no matter how detailed, that was drawn with a greasy substance on the face of a water-absorbent stone and then inked could be printed onto paper with absolute fidelity. Lithography was ideally suited for illustration (like maps) and enjoyed a phenomenal popularity during the 19th century, especially for colour printing, which required a separate stone to print each colour. The discovery of lithography was significant to the history and development of cartography. Prior to the birth of lithography at the turn of the 19th century, most maps and atlases were produced by engraving – a technique that required much skill and labour. Engraved maps were rare and relatively expensive. Lithography offered a cheaper and quicker way to reproduce maps and other images. The early topographic map sheets were reproduced by engraving techniques. This method was suitable to reproduce the hachuring method of the relief representation.

Lithographic metal plates had only rarely been used for commercial printing, in part because the image on the plate was often worn through by the printing paper. In 1904, an American printer accidentally discovered that the lithographic image could be transferred, or offset, to a rubber cylinder that could then print as perfectly as the plate and would last indefinitely. This became the most popular printing process because of its economy, long plate life, and ability to print on many different textures.

The halftone colour printing, the process still used today to reproduce full colour, was introduced in the 1890s, but many years passed before its full potential was realized. Although colour reproduction theory was fairly well understood, the lack of colour film restricted colour work to studios where the necessary separation negatives had to be made directly from the subject, under the most exacting conditions. Reliable colour film became available in the 1930s and '40s, and colour reproduction grew both more common and more accurate.

The development of offset printing method was very important for cartographers. This was the first method that let the cartographers to reproduce their colour maps economically without any constrain on the used colours or lines. However, cartographers regularly used spot colour printing methods instead of the process colour methods, which were the most common methods for colour reproduction, especially for colour photographs. In the early years of colour offset printing, it was not unusual that a map was printed more than 10 spot colours, which made the printing process quite expensive and required special care and treatment on the technology and the printing paper itself.

With the development of photography, screening methods (halftone dots) were used to reduce the number of printed colours by using the tints of colours.

The foundation of ICA

The International Cartographic Association was established in 1959. The foundation followed the birth of a new era of rapid and substantial development of cartographic technology. In the 10–15 years after World War II, there was a continuously increasing worldwide demand for maps (including not only topographic, but mostly road, city and tourist maps as well thematic maps). An almost simultaneously occurring wave of innovations further revolutionized the map production process. Plastic drawing materials which were dimensionally stable were invented, new methods, like scribing on coated polyester material replaced the conventional ink drawing.

Typesetting machines were also very important in cartography because these machines could replace one of the most time consuming processes of map production: the hand lettering. The first mechanical phototypesetters involved the adaptation of existing typesetters by replacing the metal matrices with matrices carrying the image of the letters and replacing the caster with a photographic unit. The industrial application of this idea resulted in the Fotosetter (1947), a phototypesetter manufactured in the USA by Intertype. Very soon, French, German and Russian models were invented. Later models with a separate keyboard printed more than 28,000 characters per hour. The third generation of phototypesetters appeared in the 1960s, in which all mechanical moving parts were eliminated by omitting the use of light and therefore omitting the moving optical device responsible for operating in its field.

Dr. Carl Mannerfelt, from the Esselte Map Service (Sweden) initiated a co-operation of map production experts. He invited a number of foreign experts in different areas of map production to exchange information on the technological innovations (including map editing, compilation and reproduction). It was in 1956, and due to the Cold War period, only Western countries were invited. The main reason of the success of this first meeting was that the participants focused on a special area of cartography: the map production. There were no scientists; they were all practical cartographers, map producers. When ICA was formed the scientific aspects became more important (international co-operation in the field of cartography) than the technical aspects. (According to the final resolution of the Esselte Conference on Applied Cartography, the planned international organization should concentrate on such aspects of cartography as are not already covered by existing organizations, like IGU, FIG etc.).

On the first ICA General Assembly in 1961, 26 countries were inaugurated as member countries. The Statutes as adopted in 1961 did not represent either governmental or commercial cartographic interest. Its aims were the study of cartographic problems, the co-ordination of cartographic research involving co-operation between different nations, the exchange of ideas and documents (and later digital data), the training of cartographers and encourage the spreading of the cartographic knowledge. However, in the first years of ICA when the relationships between IGU and ICA was a part of a long discussion it was said that cartography as a technical science might be subject to commercial and governmental influences. It was really a fact that the Esselte Conference on Applied Cartography in 1956 and the other early meetings were initiated by private map producing companies so this was probably the main reason that socialist countries were not invited and started to become ICA members only after 1964 (nevertheless, it was again a political issue at that time).

The definition of the term cartography was also an important task of the early years of ICA (Stéphane de Brommer, the Vice-President of ICA and the chairman of the Commission on Education and Training has dealt this issue). The Multilingual Dictionary of Technical Terms in Cartography (edited by Emil Meynen in 1973) declared the term as "the art, science and technology of making maps, together with their study as scientific documents and works of art". This definition was a compromise after a long discussion inside the association, but Prof. Konstantin Salichtchev, the ICA President (1968–1972) still regretted that the final definition was concentrated too much upon the map production and did not concentrate enough on a scientific approach. The definition later has been changed due to the computer technology, but this issue still shows the importance of the output in cartography (Ormeling, 1988; Salichtchev, 1979).

ICA commission on map production

The initial statutes of the ICA only roughly described as to how the commissions should be established. The first ICA commission on focusing partly on the reproduction methods was the Special Commission on Automation. This commission was established in 1964 and in 1980 it was renamed to the Commission on Computer-Assisted Cartography. The commission had very general terms of reference, which later became more specific including the development of cartographic systems. The only objection to the commission's work was that it was usually highly based on the hardware elements of computer cartography (including output devices), but the cartographic presentation was often hidden in the background. This opinion on computer-assisted cartography was still valid in the 80s. The series of AutoCarto conferences (USA) had a strong influence on the technical development of computer cartography, but the results of this dynamic process were used only in the most developed countries.

In 1971–1972, a questionnaire result demonstrated that ICA member countries thought that there was a need for a commission to study practical map production methods and techniques. The Commission on Cartographic Technology was established in 1972 with the following terms of references:

1. To review current cartographic techniques and processes;
2. To disseminate information on these techniques and processes;
3. To organize commission meetings.

In order to avoid overlapping with the above mentioned Special Commission on Automation the new commission restricts its activities to study:

- colour proofing techniques (which is an important part of the map production process),
- register systems (these systems were developed to make the offset printing process smoother and to avoid mis-registering),
- an evaluation of techniques for the production of small editions of multi-coloured maps (this problem is still existing, but the digital printing methods are now easily available, which was a not a case when the commission was originally formed).

The commission was very active in the early years, and they continuously monitored the new development of the map production technology. However, due to the production of different written manuals and handbooks their activities were partly slowed down. The name of the commission changed several times and now it is called Commission on Management and Economics of Map Production. Although the subjects of the commission has changed comparing to the early years, matters like printing-on-demand, web publishing and archiving should be researched by the commission since the middle of 90s.

In 1984, the first volume of Basic Cartography for students and technicians was published (Figure 1). Altogether three volumes and an Exercise Manual were published. Volume 3 was published in 1996 and dealt mostly only with computer cartography. In the first two volumes there were altogether 10 large chapters. The Map reproduction chapter was written by Christer Palm in Volume 1 (Sjef van der Steen was a co-author in the second edition), but additional chapters like Techniques of map drawing and lettering, Map compilation and Computer-assisted cartography have also partly dealt (or at least mentioned) to the output part of cartography. The effect of the Basic Cartography volumes was important since the original formulation of the concept of the series cartography, like many other fields of activity within the general area of information technology, has undergone rapid changes in both form and character. Basic Cartography had an important role also in the higher education to make an internationally standardized teaching material for cartographers. However, the rapid development of computer cartography has made difficult and complicated to integrate the knowledge represented in these volumes into the curricula. In less developed countries where the use of computer technologies was late due to the limited financial resources Basic Cartography played an important role to represent an international standard of cartography. The Map reproduction chapter mentions only the traditional printing methods (offset print), but the chapter deals with other technical sub-processes (Ormeling, 1988).

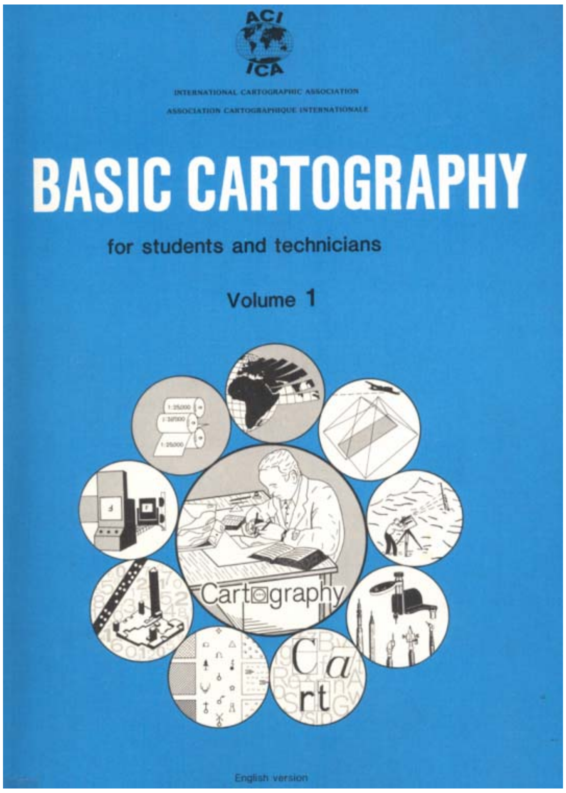

Figure 1. Cover page of Basic Cartography, Volume 1 (1st edition)

Traditional reproduction methods in the cartographic education

Cartographers had to understand the printing process, so the basics of the offset printing process were part of the higher education cartography curricula.

Erwin Raisz, one of the most important American cartographers of the 20th century felt that cartographers fell into two categories: "geographer cartographers", who wish to express their ideas with graphs, charts, maps, globes, models; and "cartotechnicians", who "help produce maps, models, and globes by doing the colour-separation or other technical works". He proposed the idea of different types of cartographers, including the cartologist, cartosophist, toponymist, map compiler, map designer, draftsman, letterist, engravers, map printers etc.

Of course, it may take time to establish independent cartography courses and before World War II practically these independent courses did not exist. The other important American cartographer of the 20th century was Arthur Robinson, who got his PhD right after World War II at the Ohio State University. In this university subject like Cartographic Production was part of the course. Raisz's General cartography and Robinson's Element of Cartography are probably the most important books in the 20th century of the American cartography, but we should mention that the cartographic education was most developed in Europe at that time (McMaster, R., McMaster, S., 2002).

In the Latin American and European traditions, the production techniques are certainly not considered part of the academic environment. They are much respected and much appreciated, but generally we will find them not in academia.

Without fully understanding the essence of offset printing, cartographers were not able to create a good symbology (which can be reproduced technically). They had to start the whole process with the definition of the printed colours, line widths etc. To increase the number of printed colours may considerably make the whole map production process more expensive (it was even more relevant around 1960–1970). Even the selection of the number of colour tints was a question of costs. It was very important in the education of cartographers (especially in the higher education where we have time to give complex knowledge and make the students understand the relationships) to clearly understand how the final phase of the map production process (offset printing) may affect the beginning phase of the map production (creating a map symbology). However, it is not obligatory to be an expert of the whole reproduction phase, but to understand its importance is necessary if we want to run our business efficiently.

At my university, the independent Department of Cartography was founded in 1953 and in 1955 we started the first cartography course. This was not an independent cartography programme, but was a specialization after the second year based on geography and geology courses. (We may call it a pre-Bologna system: 2 + 3 years). We had a series of lessons with a title Map technologies and the students had to understand the whole technical process of map producing: map drawing or scribing, all kind of technical works (photography, screening), proofing, offset printing (including binding, folding). These were not just theoretical lessons, but students had to practice all different areas. We had all technical devices (special camera for reproduction, frames for contact copies, special instruments for screenings, proofing devices, trial offset printing machine; as folding and binding were connected to book and newspaper publishing and we did not have such kind of machines, we visited printing houses to present these processes to our students). Of course, we also had similar practical lessons in the drawing part (ink drawing and scribing etc.). A student who made the whole process himself/herself was able to understand the potential errors. This is why they were able to manage the production line when they started to work at a mapping company or in the state cartography.

The first steps of digital cartography

The Geographic Information System simultaneously developed in America, Australia and Europe. The extraction of simple measures largely drove the development of the first real GIS, the Canada Geographic Information System (CGIS) in the mid-1960s. CGIS was planned and developed as a measuring tool (mostly to help the precise measures of areas), a producer of tabular information. At that time, the system could not be a mapping tool, because the most important input and output devices were not yet developed. Computer systems were unique, very expensive, and mainly used only for research or (secret) military purposes.

A second step of innovation occurred in the late 1960s in the US Bureau of the Census, in planning the tools needed to conduct the 1970 Census. The DIME program (Dual Independent Map Encoding) created digital records of all US streets, to support automatic referencing and calculation of census records. (The US Census was always very innovative: Hollerith built machines under contract for the Census Office, which used them to tabulate the 1890 census data using special punched cards.) The similarity of this technology to that of CGIS was recognised immediately by experts and led to a major program at Harvard University's Laboratory for Computer Graphics and Spatial Analysis to develop a general-purpose GIS. Early GIS developers recognized that the same basic needs were present in many different application areas, from resource management to the census.

In a largely separate development during the second half of the 1960s, cartographers and mapping agencies had begun to ask whether computers might be adapted to their needs, and possibly to make the map producing more cost effective. The UK Experimental Cartography Unit (ECU) pioneered high-quality computer mapping in 1968; it published the world’s probably first computer-made map in a regular series in 1973 with the British Geological Survey; the ECU also pioneered GIS work in education, and much else. National mapping agencies, such as Britain's Ordnance Survey, France's Institut Geographique National, and the US Geological Survey and the Defense Mapping Agency began to investigate the use of computers to support the editing of maps, to avoid the expensive and slow process of hand correction and redrafting. The first automated cartography developments occurred in the 1960s, and by the late 1970s most major cartographic agencies in the Western part of the World were already computerized to some degree. However, the magnitude of the task ensured that it was not until 1995 that the first countries achieved complete digital map coverage in a database (including digital state cadastral and topographic maps series) (Longley, 2005).

Remote sensing also played an important part in the development of GIS (and cartography), as a source of technology and more importantly as a source of data. The first military satellites of the 1950s were developed in great secrecy to gather intelligence, but the declassification of much of this material in recent years has provided interesting insights into the role played by the military and intelligence communities in the development of GIS. Although the early spy satellites used conventional film cameras to record images, digital remote sensing began to replace them in the early 1970s. At that time, civilian remote sensing systems such as Landsat were beginning to provide vast new data resources and to exploit the technologies of image classification and pattern recognition that had been developed earlier for military applications. Weather satellite images had also an important role especially in meteorology, where the low resolution of the early images was good enough to improve the precision of global weather forecasts. Nowadays satellite remote sensing provides the best quality large-area coverage database on Earth (Harris, 1987).

Although there is no close contact to the output side of the cartographic process, another important step of digital cartography has to be mentioned: the global satellite navigation systems such as GPS. However, GPS became widely used in the civil cartography only in the 21st century, although for military use it was already available around 1980.

Computer printers

There is no space to give a comprehensive overview of computer printing in this paper, so only the most relevant techniques will be discussed. The development of computer technology before the release of personal computers was focused on the calculation speed. This was the time when the theory of the geographic information systems was developed. In the 1960–1970 years, there was not too much focus on output devices in informatics. At that time matrix printers were nearly the only opportunities to make output from digitally stored data. These devices were produced to print text (characters) based on simulating the well-known “output device”, the typewriter using a so called impact printing. However, these devices were driven by the computer at a much larger speed than any human could do. What was much more important in the cartographic point of view is the print size. In the industrial and scientific environment where financial resources were available such kind of large format line matrix printers and (later) dot matrix printers were used. This large output size (wider than the 80 columns of an A4 sheet) became available in the 70s. The Harvard Laboratory for Computer Graphics (and Spatial Analysis) developed an automated mapping application called SYMAP, to produce isoline, choropleth and proximal maps on a line printer around 1960 (Figure 2). This technology was used only in research institutes where line printers were available. This printing technology has never been used together with personal computers, however the technology was long time used in business environment (bulk printing), but finally the large speed laser printing replaced the old technology. This technology probably did not appear at that time in the cartographic education, but nowadays it is widely taught when we want to present the evolution of digital cartography and geographic information system.

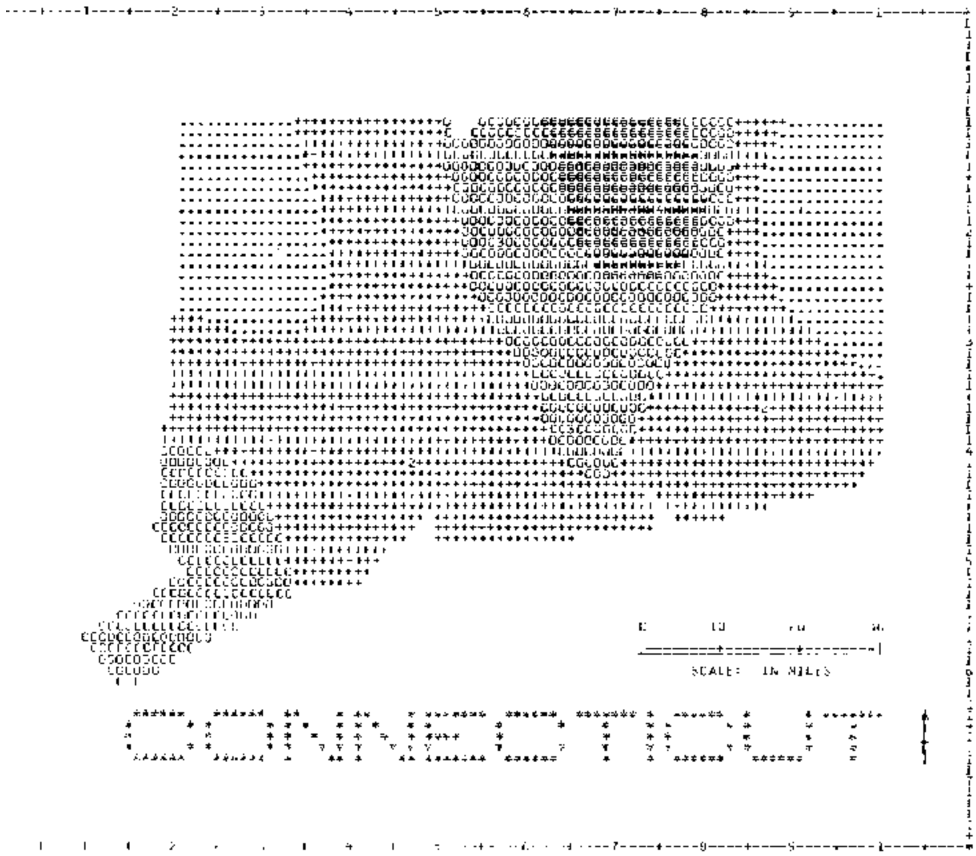

Figure 2. SYMAP example around 1965
http://www.math.yorku.ca/SCS/Gallery/milestone/thumb8/popup/bssn1_popup1-21.htm

Dot matrix printers were developed around 1970. The very first printers used 5 × 7 dot matrix to form the characters; later the 9 × 9 dot matrix became standard. In the 1970s and 1980s, dot matrix impact printers were generally considered the best combination of expense and versatility, and until the 1990s they were by far the most common form of printer used with personal computers. Early dot matrix printers were notoriously loud during operation, a result of the typewriter-like mechanism in the print head and they produced printouts of a distinctive "computerized" quality (the quality of text printing was far from the real typewriter text). Although the very first dot-matrix impact printers lacked the ability to print computer-generated images it has changed soon and encouraged the PC users to buy this relatively cheap output device. The speed and graphic quality was very poor, but users had no other opportunity to print their documents, including maps. This was also the first low-cost option for colour printing (although they were also 9 pin dot colour models). When the manufacturers wanted to improve the printing quality of their models, they invented a 24-pin dot matrix printer around 1985. The print quality was not comparable to the actual models, but these were the first printers to allow the users to print colour photographs (even such prints might take some ten minutes or more even in a small size). The colour dot matrix printers had no chance to become wide spread because a new technology, the inkjet was invented and in some years this technology replaced the dot matrix printers especially on the home market. The effect of colour dot matrix printers in cartography was nearly invisible due to the fact that only few manufacturers developed such models (Apple, Citizen, Epson, Panasonic), and the print quality was really poor (printing stripes remained visible on the paper, Figure 3). Some colour dot matrix printer models are still on the market, but only for printing receipts (Zable and Lee, 1997).

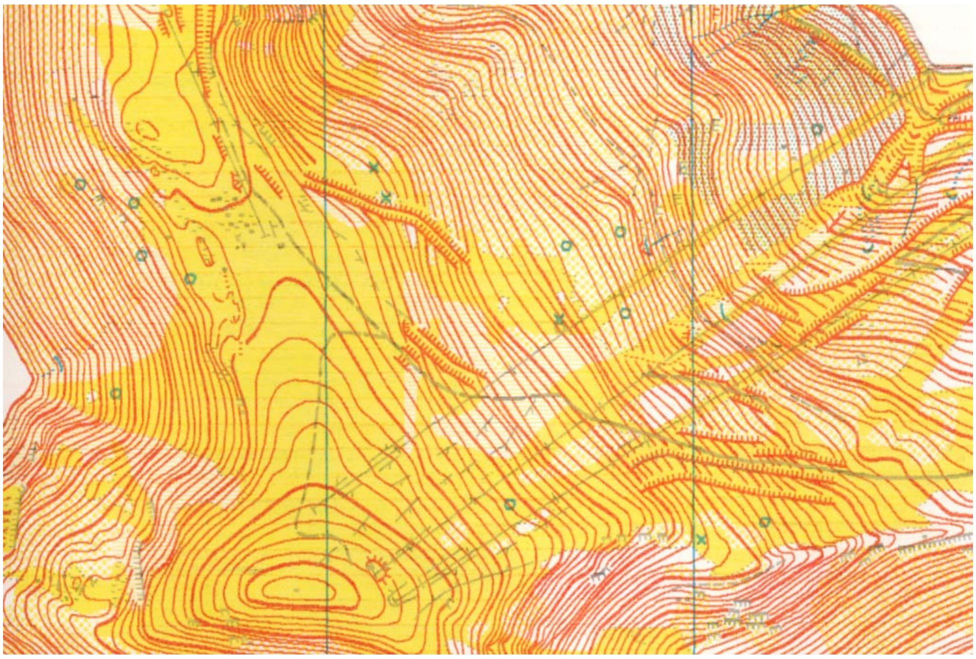

Figure 3. 24-pin dot colour matrix printed map

The very first special output devices used in cartography was the pen plotter. Compared to modern printers, pen plotters were very slow and cumbersome to use. Users had to constantly worry about a pen running out of ink. If one pen ran dry at the end of a plot, the entire plot had to be re-done, which was very time consuming. Plotters could only draw lines; they could not reproduce raster or photographic images. Despite these limitations, the high resolution and colour capability of pen plotters made them the colour hardcopy output device of choice until the late 1980s especially in technical drawings and CAD graphics, which consisted of simple lines like cadastral maps. Only the inkjet technology has made pen plotters obsolete.

In a drum technology papers were fixed and pen was moved in a single axis track and the paper itself moved on a cylindrical drum to add the other axis or dimension. Where the paper was fixed on a flat surface and pens were moved to draw, the image was called a flatbed plotter. This type of plotters regularly can use several different colour pens to draw with.

CalComp was incorporated in 1958. It was one of the first companies in the United States to market peripheral products designed specifically to work with computers. CalComp's appearance coincided with the first wave of acceptance of computers by such mainstream businesses as banks and insurance companies. In 1959 the company developed the world's first drum plotter, but few expected the instrument to grow into CalComp's strongest product line (Figure 4.). The company introduced a complete line of drum plotters in 1962. During the mid-1960s computers continued to advance and become more user-friendly through the addition of peripheral products such as keyboards, monitors, printers, and plotters such as those designed by CalComp. By 1968 between 80 percent and 90 percent of all plotters in existence were manufactured by CalComp (prices were between $3,500 and $50,000).

The other important plotter producing company of the early years was Versatec. They produced the first commercially successful electrostatic writing technique plotter that produced information on paper directly from digital data sources in 1970.

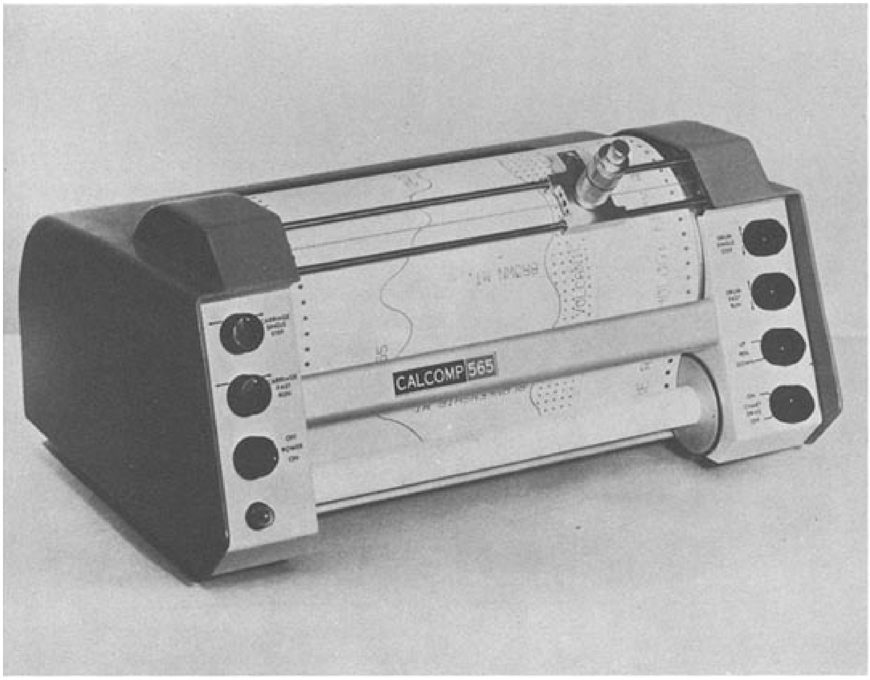

Figure 4. CalComp model 565, a 12 inch drum plotter (1959)
http://design.osu.edu/carlson/history/images/pages/calcomp565_jpg.htm

Hewlett Packard and Tektronix produced small, desktop-sized flatbed plotters in the late 1960s and 1970s. The pens were mounted on a travelling bar, whereby the y-axis was represented by motion up and down the length of the bar and the x-axis was represented by motion of the bar back and forth across the plotting table. Due to the mass of the bar, these plotters operated relatively slowly. HP produced only flatbed plotters before 1980, but the model 7580A (released in 1981) was the world's first "grit wheel" pen plotter. This machine combined high speed and high line quality in a small package at a price less than half that of comparable products on the market at the time. Small grit-covered wheels move the paper along the X-axis of the 7580A, thereby replacing the heavy, bulky components used in other plotters with a low-mass, low-inertia drive mechanism.

Plotters were perfect devices in the early years of digital cartography, but their high price made these devices affordable only for large companies. When the price was reduced, these plotters were also used in the higher education because the programming was relatively easy (very simple instructions on the plotter graphic languages) and students could use it efficiently. It was also important in the higher education that the operational method of the plotter was theoretically easily understandable. The operational costs were relatively low (pen, paper) and the devices did not require special treatment, which was important in the higher education.

At our department the first real digital output device was a simple Numonics drum pen plotter, which we acquired in the beginning of 90s. Our students wrote computer programs that calculated the coordinate network of various projections, but due to the lack of suitable output devices students edited these drawings manually (buying the Numonics device we had the opportunity to use the digital technology, which made this project more interesting for our students).

Actual computer printing technologies

Since the graphic operation systems and graphic environments were released around 1984–1990 and graphic software also become available computer printers started to be a part of a cartographic workstation. Laser printers were fast and reliable, but colour models were very expensive in the beginning. This technology does not allow larger models than A3 size. The prices were falling down in the last few years so laser printers (including colour ones) are real options now even in the home market.

Inkjet technology replaced the dot matrix printing in the middle of 90s (Canon released their very first model in 1981 and HP did the same in 1984). Although black and white models were less expensive in the beginning, the price difference between colour and black and white models was not very high. In some years black and white models have totally disappeared. This was the first technology that reached the photo quality at a reasonable price. Although photo quality and colour accuracy was not necessary for cartographers, it helped to improve the technology (for example using more than four inkjet cartridges to be able to reproduce more colours). Before manufacturers reached this goal, they just had increased the resolution of their models up to 1200 dpi. Not only the photo quality was the issue of resolution, but also the quality of ink and paper.
The large format models were much more important for cartographers, although primarily the large format models were developed for CAD. This was the reason why the first large format models were concentrated on line drawing instead of filling area with homogenous colours.

Other technologies like dye sublimation, thermal vax, electrostatic printing were so expensive that only state cartography institutes were able to afford that. The operational costs were so much high that inkjet models replaced these special printers in some years. These special technology models are still available and they used where colour accuracy is a key factor, but colour management is also available for inkjet models.

Inkjet printers appeared soon in the higher education. A4 and A3 models were available at a reasonable price already in the first part of the 90s and the price range of large format models was also reachable for a higher education department. Even students could afford such printers in the second half of 90s (Zentai, 2009).

Computer printing in the education

Only when the digital printing became an affordable option in the higher education it was really important to teach not only the cartographic software, but also the digital printing process. Although the first printers were not really sophisticated, their appearance gave the users a freedom not to depend on the expensive, time consuming process of offset printing. In the beginning, digital printing was just treated as an additional proofing method, which substituted neither the offset print, nor the proof. The real advantage of this new option was the low cost and the speed. The speed was really slow compared to the actual capabilities, but it was much faster than any contemporary analogue method.

Students were very interested in the digital technologies (as the younger generations regularly did so) so they wanted to use these technologies as early as the higher education institutes could provide them with the opportunity. It was also important to teach the theoretical background of the digital printing process, which has considerable differences compared to the traditional offset printing. One of the most important differences was that colour digital printing used a CMYK colour model instead of using spot colours, which was very common in the traditional map printing. This difference is also influenced the composition of map symbols (colours, line widths etc.). In the early years of the digital era, we had to take into account the weakness of the technology. It was very important to make the students understand these characteristics of the printing process.

As the price of computer printers decreased, these devices become part of the home computer systems together with scanners. The Internet era has made the access of information (especially the IT information) much easier than any previous time. Such kind of knowledge was partly taught in secondary schools, but it is still necessary to teach the theoretical and technical background to the cartographers. It is similar to the offset printing era: some cartographers became the experts of the technology and they were responsible for that part of the process. Nowadays we also have only few cartographers who are experts and understand the process, and the rest of them (as any other user) just presses the print button and trusts in the software and hardware.

It is also necessary to mention the new output device: the screen. More and more maps are planned (or at least viewed) on the screen of computers, mobile phones, GPS devices, personal digital assistants. To visualize the digital information efficiently students have to be familiar with the characteristics of these new "devices", so such kind of subjects should be included in the curriculum.

Summary

As cartography became a science and independent cartography courses and curricula were implemented in the 20th century, the content of these studies has been developed continuously. After the International Cartographic Association was formed, they set up commissions to encourage the cooperation of the scientists and higher education experts of the member countries. The ICA Commission on Map Production was established in 1964 and played an important role in developing and standardizing the modern reproduction techniques of cartography. The teaching of map production techniques in the higher education was also influenced by the commission, especially in the less developed countries. However, as the computer printers became widely used this influence started to decrease. Cartography curricula tried to follow the development of these output devices. Even today, when digital maps are the most important products of cartography we have to teach the visualization on computer screens. Nevertheless, the development is continuous: 3D screens and other devices are coming making new challenges also for cartographers.

Acknowledgments

The project is supported by the European Union and co-financed by the European Social Fund (grant agreement no. TÁMOP 4.2.1/B-09/1/KMR-2010-0003).

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