THE 21ST CENTURY WORLD – NO FUTURE WITHOUT CARTOGRAPHY

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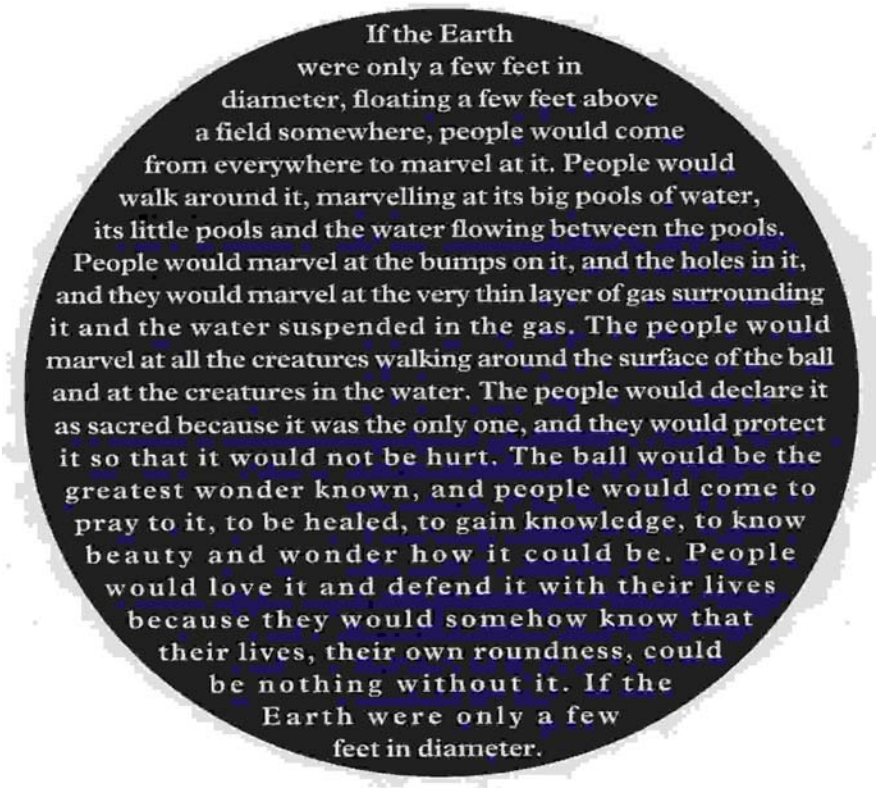
Abstract: Although quite recently named, Cartography is an expression of one of humanity's most ancient and fundamental impulses - mapping. This paper reviews its origins, nature and growth and, with the increasing support of technology, its essential role in representing and helping resolve the problems facing our fragile Earth in this 21st century. It is also proposed that, while the cognitive spatial consciousness from which it grew may have even pre-dated natural language, the language of cartography itself has been seriously underused by the majority. Until recent decades, most people only read (used) the products of this language. Today, especially through technological advances such as computers and the Web, these restrictions are being lifted as more people are becoming involved in both interpreting and creating cartographic products (i.e. truly using the whole language of Cartography). With this in view and with the expansion of the field of GIScience, the vital importance of Cartography must be recognised to ensure that it is developed as a core part of that science and not just as a peripheral tool for representation.



Prologue

This little poem *(origin unknown)* expresses delight and wonder but also embodies the fears for our world as we journey into tomorrow. But it can also be interpreted as a challenge to preserve the environmental sustainability of this precious globe…the home of humankind.

If we were, now, just entering the 20th century, our fears for the future would justifiably be much greater. The traditional but still developing professions of surveying and cartography had already begun to raise awareness of the world and its problems, but the technologies of these times could not have matched the enormous tasks which face us today – one hundred years on. And yet, only 70 years later, men would reach the moon and could look back at the Blue Planet in all its glory. The last half-century has been a period of unprecedented innovation in science and

technology and, with current facilities for Earth imaging and data capture, we are now able to recreate much of he poet's vision. But such views, with their high resolution data content, are not only objects of wonder. They also provide a virtual environment for research, and this is where the unique facility of Cartography, in all its manifestations – from visualisation to communication - plays such a vital role[1].

The New Millennium – at last!

The 'millennium' theme has featured strongly in recent ICA conferences, with predictions of what the future might hold for cartography. Recent keynote speakers have reviewed the developments and changes of the last decade, their technological characteristics and professional, financial and societal dimensions. In my oral address I will provide some brief updates, especially on the importance of spatial data quality standards, the increasing flow of data across global networks and the growing co-operation between geospatial scientists. I will also assess some of the newer modes of delivering spatially-related information to users. It is worth noting, however, that the pace of change towards an electronic future is variable across the world. While it can be argued that we are all being pulled inexorably by technology in the same direction, we will not all arrive at the 'destination' at the same time (a point made through anecdote by David Rhind in Ottawa, 1999). Even in so-called advanced (commercially-oriented) societies there can be perturbations in the graph of change. For example recent re-evaluation of New Technologies caused a slump in technology/telecommunication shares in the world stock markets, and new leadership in the USA could affect agendas for projects such as Digital Earth.

Although showing continued confidence in and excitement about the future of cartography, all recent keynote speakers, to differing degrees, have predicted the demise of the professional 'cartographer', at least as he/she has been defined in broadly current times. And it is from this thought that I begin my own review of the present and future of our subject as it is increasingly employed by both scientists and lay people to help explore, analyse and understand our potentially fragile world. The cartography which has characterised most of last century is certainly changing. Some forms may have already disappeared, and with them the participating practitioners. I too am optimistic about the expanding future role of cartography but my views on *the nature of its use*, and the size of its user base, are influenced by my personal interpretation of the term *'using cartography'*. In the past cartography was largely a manufacturing industry (i.e. by professional map makers/cartographers) and the consumers of its products were the map users. What I envisage is a *change of emphasis*. The traditional 'manufacturing' scenario will certainly not disappear, any more than paper books are likely to disappear from our lives in the foreseeable future. When Vanessa Lawrence, the new Director General of the UK Ordnance Survey (and who is rapidly moving that organisation into e-business) was asked if she saw a future for paper maps in this electronic vision she replied with enthusiasm "Most certainly. I believe there will always be a market for good graphic products." Although technology changes lives, not all technological innovations have totally transformed the way we did things before. Despite credit cards we still use cash; despite increasingly sophisticated methods of travel we still walk and cycle when appropriate; despite TV, satellites and home PCs we still listen to the radio and attend live entertainment. So there will continue to be a cartographer-client relationship for some special products and services (and not only paper-based). But to develop my ideas on what I will call 'truly *using* the special language of cartography' I will first re-examine the definition of the field and how the use of cartography is changing.

An approach to the analysis

Although 'presentation' and 'communication' have traditionally described our subject, the theme of this address (perhaps just a reminder to some) focuses on the essential and increasingly central place of 'cartography' in scientific geospatial investigations as well as in communication. I suggest that the human impulse to make pictures and to map, although evident in prehistory, early history, and amongst indigenous peoples today, has been the active preserve of the few and has remained largely undeveloped within the wider population until very recent times. True innovators of the past (and especially architect-builders and engineers) depended heavily, if not completely, on the fundamental and instinctive human trait of theorising, testing and developing ideas graphically and visually rather than with words. However, as these people were, first and foremost, creators of artefacts (including buildings and even maps), and seldom part of those '…small and specialized segments of our race which have had the habit of scribbling *(i.e. writing about things! MW)*' (White, 1978), their creative procedures have '…been by and large an invisible and unrecorded aspect of the history of civilization.' (Petroski,1989). Although cartographic activity has ancient origins and increasingly flourished from around the 16th century, most of the record (especially from the 18th century onwards) is of presentational, printed products alone – largely the output of a small number of mapping professionals

[1] Although visual access to high quality original images is essential, humans must simplify and analyse their world in order to see and understand it properly. In spatial matters this comes down to the products of cartography (traditionally referred to as maps) – abstractions or models of reality which help reveal the truth. These products can range from a simple line map on paper to an animated view of virtual reality .

who emerged when an excess of detail demanded specialised craftsmanship to preserve legibility. These products were often described as spatial 'databases' representing physical and, later, human landscapes, etc., the pre-map images, compilation drafts, or even sketches from map-related investigations which may have formed part of the working drawings of people such as hydrographers, archaeologists and geographers, have been lost. Nevertheless, reference texts such as 'Cartographical Innovations' (Wallis & Robinson, 1987) and the outstanding research volumes of the Chicago 'History of Cartography' project (Harley & Woodward, 1987-) do list and describe many examples, although most of printed rather than rough manuscript form. If, at its core, cartography is truly a common and specialised graphic language (Harley & Woodward, 1987-), graphic evidence of the externalised visual thinking processes (in the form of cartographic 'sketches', etc.) of specialists as part of their preliminary research activities, must have existed. But, they too may have been lost or ignored (as trivia?) by the more 'literary' historians castigated (above) by White (1978).

In this review I will first reduce 'cartography' to what may be called its basic features. This exposes examples of cartographic processes ranging from mental visualisation to the toolboxes of GISystems . I will then examine the nature, character and historical provenance of what has been called the 'mapping impulse', justify its continuity and herald its recent revival and growth within the wider community. Finally I will review the nature and role of cartography and its users, today and in the future. In relation to the latter (and as suggested in the previous section) I propose a small but, I believe, significant change in the way cartography can be viewed. In the past, with the domination of professional cartographic practitioners and their mass output, a clear dichotomy could be observed between 'makers' and 'users'. Although this may have seemed logical, even inevitable, in the past, it highlights the absence of the (creative) mapping impulse (or instinct) in the wider population, already identified in peoples from all regions and continents. It might also make us doubt the existence of what has been called a cartographic language (Harley & Woodward, 1987-). If we follow the linguistic analogy, those who *use* language to the full do *not merely 'read'* (or use) text documents prepared by others. They *also write* the language as a means of investigation and communication (e.g. keeping a diary, writing letters of all kinds, making detailed notes while reading articles, or preparing lists and plans-for-action.). The past can certainly be characterised as a time when most people (who had any contact with maps) were map-users only. Today, however, and especially with increasing facilities for interactivity on the Web, the so-called democratisation of cartography is encouraging increasingly impressive numbers to make fuller use of their own creative cartographic instincts. They are becoming more holistic, **participant users of cartography** and not just the **restricted users of maps prepared by others**. I will illustrate this progress towards such more profound 'usage' of cartography as a unique facility in both the exploration and analysis of spatial information and in its representation and communication. The process can be seen at both the informal level - sketching maps on paper or on Palmtop computer screens – and, more formally and implicitly, when employing GISystem software on desktop PCs or on the Web. Although technological advances can curtail certain personal activities (e.g. cars reducing our walking activities) it is my belief that, through the development of both computer and electronic communication technologies, we are now moving into an era when cartographic activity will grow – the technology is expanding human potential. The prospect is exciting both for increased societal awareness of the world and its problems and for continued evolution and innovation in scientific research methods.

A return to basic considerations

The map-making instinct/impulse has existed in humans for millennia, and the inventive variety of useful map-like artefacts which have been discovered would certainly challenge the innovative nature of many of the narrow, and perhaps even predictable technology-based products of today. Names such as 'cosmographer, hydrographer, geographer, philosopher, platt-maker, and chart-maker..' (Wallis & Robinson, 1987) and even chorographer, reflect the diversity of the disciplines and occupations of past mapmakers, but it was not until the 19th century that the Portuguese Viscount de Santarem coined the word 'cartography'. Although defined first as 'the study of ancient maps', it was soon adopted as a general term for the future. While it has been criticised as perhaps inappropriate for the modern discipline, it also shares its relatively recent adoption with terms such as 'palaeontology', 'ecology', 'biology' and 'psychology'. In the first half of last century cartography was defined as the manufacture, or the art, science and skill of making maps (a definition still common in modern dictionaries). Since then various alternatives have been offered, including the very specific 'information transfer that is centred about a spatial database which can be considered in itself a multi-facetted model of geographical reality' (Guptill & Starr, 1984). As the ICA's concern is to include all those who believe in maps and who are involved with their creation and use, before 1991 the official definition was 'the art, science, and technology of making maps, together with their study as scientific documents and works of art' - including all types of maps and 3D models. The current ICA definition is even more inclusive, 'the discipline dealing with the conception, production, dissemination and study of maps' in all forms (ICA, 1995), classifying even map publishers and shopkeepers as 'cartographers'? My personally preferred definition has always been more focused on the creative design of the traditional graphic product. Indeed I still warm to Muehrcke's statement that 'Cartography happens at the design stage. Design is the creative heart and soul of our field' (Muehrcke,

1996). However, when we observe the uncertainties and misunderstandings of some new and often cartographically naïve users of GIS or the Web (e.g. the belief that cartography is merely part of the 'output' end of a GISystem, or that GISystems have **replaced** cartography), perhaps the flexibility of the current ICA definition is a disadvantage. This 'challenge' from GIS has been characterised vividly by Muehrcke, 'This new technology (GIS) is supposed to take us beyond maps. If we are to believe GIS proponents, then analog cartography is dead and digital cartography is dying…..they say that the paper map has been dead for a long time.' (Muehrcke, 1996) Believing as I do in the fundamental importance of cartography as a core rather than a peripheral facility, such observations, exaggerated or not, frustrate me. I thus feel the urge to probe more deeply into cartographic fundamentals to seek the foundations of the subject. A useful start is provided by Kraak and Ormeling (1996, Figure 1.3). When describing the nature of spatial data they offer a sequence of abstraction and transformation from 'reality', through the 'digital landscape model[2]', the 'digital cartographic model' to the visual 'map' and finally to the 'mental map' as interpreted in the mind of the viewer. My view of the cartographic process can be summarised as follows:

1. Cartography is primarily (but not solely) the production of a visually-perceivable graphic image (normally an abstracted model of the reality being portrayed). The cartographer "selects, generalises and researches, but in the end he must put his materials and determinations into graphic form." (Robinson, et al, 1995). Naturally (as in the past) this image can be formed and retained in the 'database' of the mind or (more conventionally today) in computer digital form, before being externalised for scrutiny and application.
2. What I would call the true 'cartography' first emerges as an embryonic (digital) representation of the spatially-located, abstracted elements of the subject (e.g. the 'landscape model' of Ormeling and Kraak, 1996) - as points/lines/polygons stored in an appropriate database structure. Once externalised (made visible) and even before graphic differentiation (design) is applied to its elements, a map reader may still be able to interpret the represented landscape from the patterns of point and line, or the differing line characteristics (e.g. jagged coasts or smooth railway curves). A typical example of this form of rudimentary map is a quick pencil-drawn sketch on the 'back of an envelope'. The fact that such a simple image can be recognised and used as a map confirms its basic cartographic authenticity.
3. The physical locations of the elements of the landscape model can be determined in a number of ways:
    - from instinct and experience – as in a sketch derived from a personal cognitive map (e.g. the memory of the street plan round a childhood home.)
    - from belief of where they should be (e.g. an attempt to draw a contour pattern to represent a U-shaped valley)
    - from survey measurements made in the field or derived from another source (e.g. photogrammetry)
    - from any of a variety of computations made on the above model elements or from their combination. (e.g. projection graticule; interpolated contours; assigned buffer round a lake shoreline)
4. The next stage is to introduce character and contrast through the application of graphic (and other) variables. Initially this will help make the image more legible and comprehensible (bringing the model to life). Naturally at this stage there are a variety of ways in which the map may be designed to draw attention to 'this' or 'that' or to define its communicative or analytical purpose! Before this happens it is just a compilation (e.g. from the topographic survey). However without the 'locations' in the first place, no design can be applied and so the fundamental skeleton of the cartographic product must be recognised as the 'landscape model'.

From this simple and focused description and analysis of cartography (based on the conventional planimetric map as an example only), a variety of map types and other cartographic products can be imagined. These will range from quick hand-drawn sketches to accurate topographic map series created by national mapping agencies; from planimetric maps to 3D models, static or animated; from printed paper products to web-based GISystems offering full interactivity, multimedia and New Media dimensions. We can also, more confidently, include, as basically cartographic, many of the spatial analytical processes incorporated within a GISystem function-suite: e.g. the retrieval of map layers, overlay operations, combining layers arithmetically or logically, and neighbourhood functions (also see Tomlin, 1990). True cartographic procedures, therefore, lie deeper within GISystems than may be realised by some new users, and certainly extend beyond the visual presentation of the results of analyses, or, more briefly, 'cartographic output'. In some cases they comprise the analytical processes themselves, referred to as the "digital equivalents of analogue procedures that cartographers have used for 50 years" (Robinson, et al, 1995).

The mapping impulse and its implications

Mapping, historically, can be subdivided into manufacture and serious use, following the pattern of market demand for essential high quality products by specialists (navigators, military, planners, etc.), and the creation/emergence of

[2] Of course not always landscapes.

a professional structure to satisfy these needs (the cartographers, data collectors and providers). However I believe that enough is known from both history and prehistory that spatial consciousness and the mapping impulse are so fundamental to humans that evidence for their informal application by members of the wider population in recent centuries could and does exist.

The origins of human mapping ability, initially in cognitive form, are both primitive and ancient. Cognitive mapping can also be detected in very young children today and certainly exists in animals (e.g. bees and rats). It can be argued that these instincts are so fundamental that they not only pre-date language but may even have contributed to its early development, and that 'cognitive maps may have been a major factor in the intellectual evolution of hominids (Peters, 1978). The earliest appearance of human graphic communication may even date to the Lower Palaeolithic period (40 000 year BP). Some permanent images can certainly been dated close to these times (e.g. the totemic paintings on rocks deep in the caves of Lascaux, France, c. 30 000 BC). It is also true that 'for a long time mapmaking was almost certainly an unconscious barely differentiable form of graphic expression' (Lewis, 1987). Early man's first priority was obviously to survive, and spatial awareness with relation to safety and refuge would have formed part of the earliest manifestations of human consciousness. This spatial consciousness has been described as 'a form of re-presentation of the current perceptual input on a mental screen' (Lewis, 1987) and therefore supported a continuous state of alertness for the unanticipated and unexpected dangers which haunted our ancestors. Lewis also notes how, as individuals began to work together, they had to develop several forms of language including ways of communicating spatial information. Initially this may have included gestures (still used by people in resource-limited environments – such as during informal conversations) but it is also assumed that ephemeral graphics, on sand or any other available surface, would have played their part. Evidence of gesture is still found in the map icons of indigenous peoples today. Our distant ancestors were not creating maps in any modern sense. Indeed the need for graphic externalisation may not always have been necessary. Just as a surveyor today can gain valuable (cognitive) awareness of her study region during reconnaissance surveys, the process of active mental mapping for early communities 'may have served to achieve what, in modern behaviour therapy is known as desensitisation: lessening fear by the repeated repetition of what is feared' (Jaynes, 1976). This whole process of pre-literate graphic and 'cartographic' activity has been referred to as part of the evolution of intelligence and self-learning. This has led to the development, in homo sapiens, of four important mental capacities which could have been critical to the development of mapping skills. They are a) delaying an instinctive response to permit a pause for exploration, b) storing acquired information, c) the ability to abstract and generalise (or model), and d) the capacity to process the information and make appropriate response (Lewis, 1987).

Using the more academically-researched prehistorical and historical evidence from Europe and the Mediterranean we can detect what have been called 'a series of cognitive transformations' which have led to an awareness of the 'idea of the map as a basic form of human communication' (Harley, Woodward, 1987). Two critical aspects can be noted: i) that since prehistoric times there had grown a widely-accepted understanding of what a 'map' image represents, ii) the characteristic appearance of a prototypical map has also emerged and been broadly accepted. These concepts are important, not only at the more professional levels, but because they may have become part of a more widespread common awareness. "Whether it was intuitive or conscious, a graphic 'language of maps' was being developed." Another evolving characteristic of maps was their most common functions, namely: geographical wayfinding and inventory of real world features; representation of sacred and cosmological information; the promotion of secular ideologies; an aesthetic or decorative aspect. (Harley, Woodward, 1987)

It is interesting to note that 'formal literacy has not been a precondition for (maps) to be made or read' (Harley, 1987) equally, 'the reading and writing of linear scripts is a special accomplishment associated with a high level of social and technical sophistication' (Leach, 1976). However, although the mapping impulse is strong and very significant, the actual process of making anything beyond the simple sketch is not easy nor innate. When it comes to the manufacture of a quality product for critical applications (such as urban planning or military campaigns) great knowledge and skill are obviously required. This could be described as the true heritage of the cartographic craftsman, selecting and codifying for communication.

Until the beginning of the second millennium AD exposure to any formal mapping was highly restricted to elite population classes - social, religious or academic. Block printing dated back to the 8th century AD in the Orient but true printing (and with it the possibilities of some form of educational democratisation) did not emerge in Europe, for example, until the 15th century. 'By circulating maps…(etc).. the printing press solemnised a fertile marriage of practice and theory unique in the previous history of mankind…. The cloistered mathematician of the university now came into courtship with new problems of…surveying and navigational astronomy, hitherto the closely guarded secrets of the craftsman.' (Hogben, 1949). Due to the increasing demand for printed materials (including maps) the printer and cartographer became professionals rather suddenly in the 15th century (Woodward, 1975). Early printing also brought controls to the manuscript mapmaker who, previously, had been his own master. This led to some standardisation of image which supported the gradually increasing introduction of forms of universal education. The

development of printing has been compared to the arrival of the computer age. Both increased, enormously, the possibilities for democratisation of information and education but both suffered from barriers to this vision. In the earlier centuries it related to the absence of political will and structure for such education. To use the example of Europe, before 1000 AD schools were connected to monasteries and churches but often contributed little to the general spread of knowledge. The universities began around the 12th century but more widely available schooling in Britain for instance did not begin seriously until the 18th century. Despite the mapping impulse and the evidence for its almost innate presence in us all, without the environment of learning it was not given much opportunity to flourish. However with the arrival of the 20th century and compulsory education in Britain, for instance, new opportunities were available to exercise the potential. The first half of the 20th century also contained two world wars when national populations were exposed to unusual crises, training and new ideas. The narrowness of these Eurocentric examples could be criticised, but they can be matched in different ways the world over. So in summary I see a near-innate facility for mapping which has evolved over 40 000 years from cognitive origins. Evidence has been discovered of mapping practices and products from every inhabited region of the globe. The majority of this is formal or institutional (government or religious) although there is also evidence of 'everyday' mapping. While the major mapping activities, certainly until the 19th century, were restricted to few cartographic professionals and motivated scientists, the 20th century has seen a significant degree of democratisation including access to education at all levels, military training for the masses, the expansion and refinement of printed media, and the growth and expansion of communication systems (radio, telephone systems, TV, the Internet.) Market forces have reduced the costs of media hardware and software and many developing nations are now able to jump some stages of technological development from near-indigenous status to computer literacy!

There have thus been around 40 000 years of spatial awareness/mapping development, 2-3000 years of more clearly identifiable mapping activities, over 500 years of printing but only in the last 200 years has the wider population been exposed to the democratisation offered by that technology. Finally wider universal education has existed in many world regions for less than 100 years, with barely 50 years for acclimatisation to the post-world-war experience. This leaves barely one full generation having been exposed to the environment of computers and global communications. Nevertheless, an increasing proportion of the generation alive in the 3rd millennium (from all age groups) is making full use of internet resources, including mapping. These range from simple map search and viewing to serious interactivity with Web-based software and data resources and heralds a transformation in both informal cartographic education and, more importantly, a growing intelligence about spatial problems.

The nature and use of cartography in the 21st century

In this paper I have tried to re-centre cartography from what could have become an eccentric (even irrelevant) position in the eyes and minds of those non-map professionals new to the field of mapping science. Cartography in all its ramifications (Visualization, Virtual Reality, Communication, etc.) is still a largely unexplored and un-researched facility. If it was abandoned as a field for research and merely left in the hands of technology-driven market forces, it could become fixed in a time-warp, wither and lose all of its potential for good. Of course this will not happen, as cartographic products in all their forms (including maps) remain in the seductive overlapping zone between science and art. Whether as tools or simply attractive artefacts (on paper or on the Web) people like them. Specialist cartographers must continue to explore their potential for research, education and even entertainment. Most fields of future development for mass consumption lie in web-based products, but there are at least three other important aspects for consideration: government-based mapping agencies, visualization and virtual environments, and the cartographer-client relationship for the creation of customised products of the highest quality.

As David Rhind explained in Ottawa 1999, **governments** are the major employers of cartographers world-wide but, as is happening in the UK, this will change as the agencies move towards e-business. Their contribution to the essential frameworks of geospatial data structures will grow and the data they market and offer across the Web will provide additional major incentives for the expanding market of the true and holistic users of cartography .

The field of **Visualization and Virtual Environments** encompasses the scientific aspects of modern cartography and is led by a focused group of researchers. Collaborating with leaders in the field of Scientific Visualisation they are making pioneering investigations into the power of their visually-based medium. As the true complexities of global problems emerge the need for special visualisation tools to investigate both the problem and the huge related databases becomes critical.

One of the most interesting developments over the past decade or so has been the growth of **small cartographic service providers** all over the world, dedicated to meet the often traditional needs of map clients. Initially they concentrated on using desktop systems to generate traditional paper-based products (maps and atlases). Many, however, have moved with the times and client-need to include products such as GISystems, animated maps, and cartographic web-sites. In the context of our own British Society of Cartographers I have always referred to them as

'super-cartographers' and I have every reason to believe that, as long as the demand continues, these individuals and small companies will carry the banner of high-class cartography the world over.

Finally we come to **the hypermarket of the mapping business** – the World-wide Web. Obviously this will continue to be accessed through desktop systems for some years although prospects of powerful home-centred systems as well as enhanced WAP-based mobile communicators could reduce the importance of 'place' when it comes to accessing information of any kind. However so volatile is this field of Web Cartography that it must be subjected to critical appraisal. A brief SWOT analysis of the environment can identify the following:

Strengths: A huge range of cartographic-related facilities which can be linked almost seamlessly to many other fields thus providing potential for education, unrestricted by subject boundaries. The fun and excitement which can be experienced in this environment has great potential for widening and deepening the learning pool and attracting more students to its banks. People learn quickly and yet traditional education can drag out the process in such a way that it leads to learning atrophy. Web-based learning has the potential to overcome many of these problems.

Weaknesses: The strengths of the Web also embody some of its greatest weaknesses – danger of distraction or diversion from tasks; encouragement of the 'monkey mind' which simply cannot concentrate, - and lack of concentration is one of the greatest barriers to real learning and achievement. It is also difficult to develop ways for users to tell the Web what they want from it.

Opportunities: There are many in the field of education, including access to distance-learning courses which may be of very high quality and status. In some of the wider contexts of international awareness there will be opportunities to increase understanding of both global and local problems, notably the role of geographically-based research into public health, after earlier successes based on paper atlases. This in turn could consolidate and strengthen co-operation when events such as regional disasters occur or, more generally, to help people to change, due to changing natural environments, changing economic systems, changing political regimes, etc.. Most important of all, however, is the potential for the development of people's mapping skills. Whether merely searching for specific maps to satisfy a task or becoming fully involved in the interactive potential of creating customised cartographic products, the potential of expanding user skill and confidence in cartographic 'language' manipulation is strong. This will lead such users ever closer to a situation of pro-actively *using* cartography in every way instead of just using maps by reading them.

Threats: One of the greatest threats in the shorter term could be growing dependence on this very advanced technology alone, rather than using technology-free media such as books and paper maps.

I am glad to observe that a range of facilities is emerging to meet the inevitable range of needs of both science and society. No doubt another five or ten years will bring innovations which could change or even disrupt what has gone before. But it is to be hoped that some continuity will be preserved and that the data and information providers will continue to meet the needs as identified and not to the detriment of what could become minority markets.

Conclusion

My life in cartography has matched, almost exactly, the transition from the 'truly traditional' (pre-computer) to the new world of the Web. However I have never accepted the idea that traditional cartography was just a collection of 'flatlands' (Tufte, 1990). My interests having combined hillshading (i.e. the creation of 'virtual' 3D mountains), the construction of block diagrams and panoramas (traditionally and on computer) and even the building of relief models. I thus have no problem with the inclusion, under the term 'cartography', of everything from terrain flythroughs to visualization analysis tools. What I have called 'The Heart of the Matter' (Wood, 2001) is that cartographic products have always acted as aids to externalised thinking, or external cognition (Scaife and Rogers, 1996), from lines drawn in the sand through maps on rocks, wood, paper and, today, to animated interactive environments in cyberspace! They are all part of the great cartographic Family which no doubt will continue to expand with the technology.

The problem of definition is one of the reasons why I have sought to reassure myself of the rock-solid origins of the 'mapping impulse' and how it relates to the need to re-develop our powers of visual thinking and to re-examine and re-centre cartography within the new world of Geographic Information Science. As some of the societies involved in other aspects of data collection, etc., have experienced changes of emphasis on certain of their traditional core themes, they have increasingly turned towards application of their special skills in the spatial information sciences. Inevitably this involves heavier use of common software such as GISystems in addition to Digital Image Processing (DIP) programs, both of which clearly have cartographic operations within their core functionalities.

This review, primarily, highlights the essential and fundamental human characteristic of spatial consciousness. It not only supported people's travel and survival in their prehistoric environment, but also represented the seeds of

language and what has become one of the most powerful facilities for communication about spatial matters and for spatial exploration and analysis. An important result of the early cognitive transformation from 'internal' to 'external' was the idea of the map, "…what was actually perceived – was modified with the help of maps….both perception and representation became increasingly structured by different maps models". There has also been increasing recognition within society (from prehistoric times) that "….the map could record and structure human experience about space. Whether it was intuitive or conscious, a graphic 'language of maps'….was being developed" ((Harley & Woodward, 1987-). Intermittent low-key employment of this language (both as creation and reading) and recognition of its value eventually led to an industry of paper map production to serve many purposes. But this, in turn, led to a dichotomy for the wider population, who made use of only one facility of the language – that of reading and interpretation. The holistic development of both creative and interpretive applications has had to wait for the developments in computers and electronics. Today, not only is everyone beginning to engage full cartographic language facilities through friendly software and, especially, the World-wide Web, but pioneering cartographic scientists are developing advanced tools for data exploration and analysis as well as representation.

As GIScience advances (and at times threatens to engulf cartography) it is more important than ever before to strengthen cartography as a core element of that science and increasingly research its application as both a language for society and as the most important component of GIScience itself.

Epilogue

We are now assembling the database networks and already have the technologies with which we can explore, analyse and model the precious ball on which we live. Let us hope that the energy and intellect we can offer will be up to the task of sustaining it for the future

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