Cartography, GIS and Maps in Perspective

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INTRODUCTION

The International Cartographic Association (ICA) recently asked all its member countries to redefine cartography in the light of modern developments and opinions and participants at the 1988 Annual Conference of the British Cartographic Society (BCS) were invited to offer their opinions on the following definition of cartography, adopted by the International Cartographic Association in 1973.

> "The art, science and technology of making maps, together with their study as scientific documents and works of art. In this context maps may be regarded as including all types of maps, charts and sections, three dimensional models and globes representing the Earth or any celestial body at any scale." (ICA, 1973, p. 1)

It is not the aim of this paper to redefine either cartography or maps. At the Conference open forum, some participants were of the opinion that there was no need to change the current definition; they expressed that this definition accommodates all relevant modern developments referred to by others. Some of these developments were also stated by Alistair McDonald in his provocative invited lecture on "Future Shock and Cartography".

The aims of this paper are two-fold. The paper seeks to provide support for the ICA proposition that there is a need to redefine cartography and maps. It then explores the various issues which may either provide guidelines and clues or which must be reflected within a new definition of cartography. The arguments presented here do not necessarily reflect the deliberations and conclusions of the ICA on this matter since the author was not a part of such deliberations. They merely represent the author's own, as yet tentative, attempt to summarise her reactions based on her experience as a researcher and teacher of digital cartography. The ultimate aim of this paper therefore is to provoke discussion and to encourage others to contribute towards the very difficult task of arriving at concise yet penetrating definitions of the field and focus of cartography in this age of Information Technology. I found the contributions by Bertin (1983), Guptill and Starr (1984), Robinson *et al.* (1984) and Taylor (1985) particularly useful.

WHY REDEFINE CARTOGRAPHY?

There are two reasons for seeking a new definition of cartography. Even if we limited ourselves to traditional cartography, the current definition is an inadequate and incomplete description of the subject. Also, it does not accommodate modern developments effectively. At the Conference open forum, some participants were of the opinion that many of these modern developments were outside the remit and scope of cartography. We will reconsider this point of view later.

The current definition of cartography is inadequate largely because it does not define clearly the focus of the subject, namely maps. The description of maps is circular – "maps may be regarded as including all types of maps, charts, sections . . .". This implies two types of maps, namely a subclass of specific forms, called maps, and a superclass of generic forms also called maps. The subclass of maps is defined as a "representation, normally to scale and on a flat medium, of a selection of material or abstract features on, or in relation to, the surface of the earth or of a celestial body" (ICA, 1973, p. 7). This second definition makes it clear that the subclass differs from its generic class in some ways. But, the two definitions taken together do not identify the common properties shared by all maps, which set them apart from artefacts which are not maps.

The definition is incomplete. At the Conference forum, some members seemed to prefer such a slack definition since it left the subject open-ended and thus more flexible and accommodating. This vague, unscientific and "you know what we mean" portrayal of the subject is unhelpful and detrimental to the image of cartography. Definitions are after all the easiest means of declaring the focus and scope of our activities to others. If these remain unclear and vague, the subject becomes vulnerable. We return to this later.

Why should the new definition of cartography accommodate modern developments? Guptill and Starr (1984) in their essay on "The Future of Cartography in the Information Age" describe cartography as

> "an information transfer process that is centred about a spatial database which can be considered, in itself, a multifaceted model of geographic reality. Such a spatial database then serves as the central core of an entire sequence of cartographic processes, receiving various data inputs and dispensing various types of information products."

Figure 1 presents a simplified model, representing the scope of this new cartography. Although this definition of cartography has some weaknesses, Guptill and Starr deserve credit for drawing attention to the wide range of activity within digital cartography. Their essay tends to over-emphasise the technological

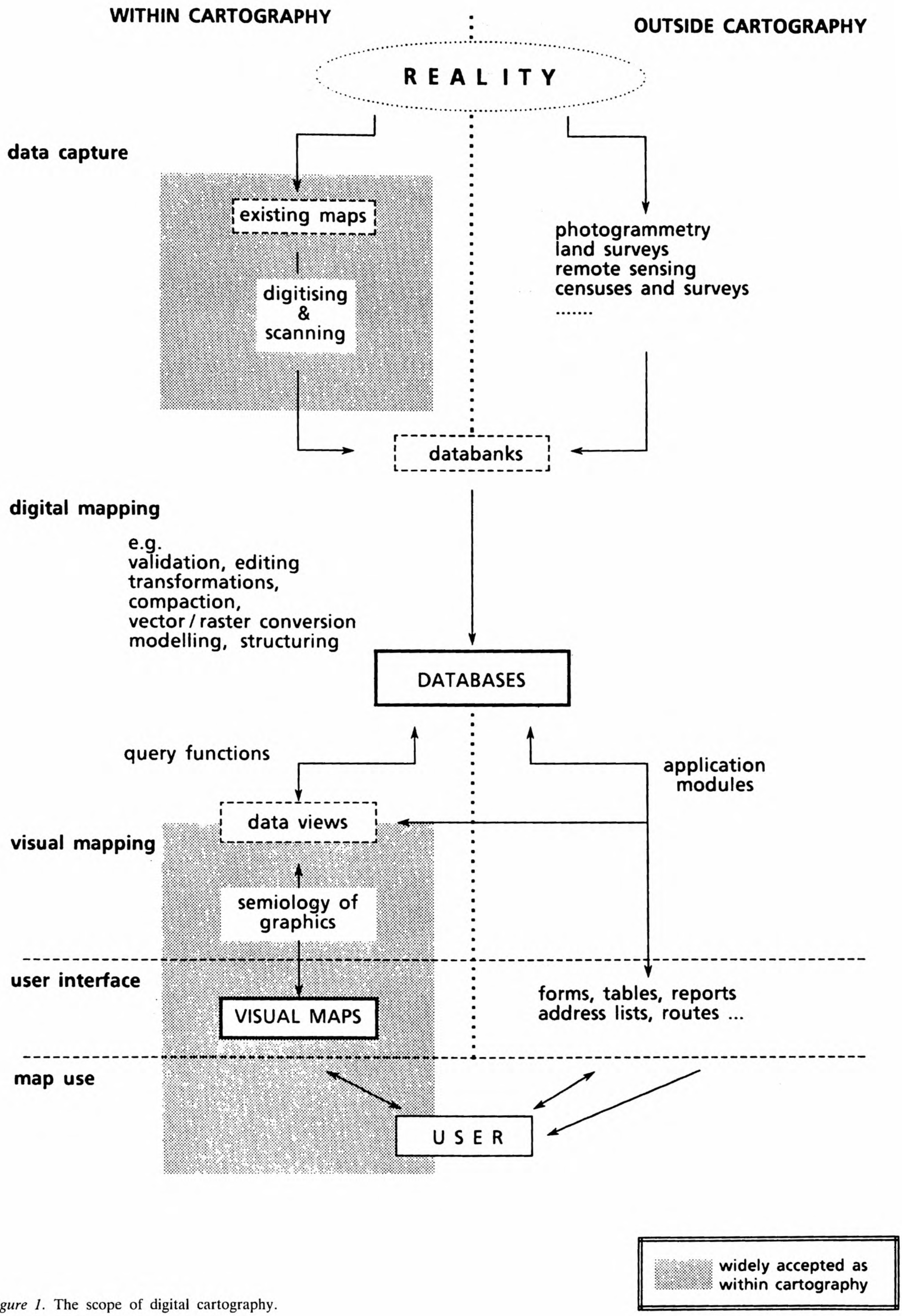

Figure 1. The scope of digital cartography.

aspects of the subject. As Robinson *et al.* (1984) pointed out, the technologic focus is just one of a number of dimensions which characterise cartography. Also, the above definition of cartography makes the spatial database the focus of the subject and regards the traditional focus of activity, the visual map, as one among a range of information products.

This interpretation is consistent with the growing perception that visual maps are no longer necessary for many functions. Mapping is not essential for automation of decision making using Geographical Information Systems (GIS). Alistair McDonald alluded to this in his invited lecture at the Nottingham BCS Synposium. This is certainly true in some routine applications. Many believe that this trend does not undermine the still flourishing subject of traditional cartography since there will always be a need for the visual product. Visvalingam and Kirby (1984) and Visvalingam (1985) stressed the need for validation through visualisation and the role of visualisation in concept refinement. The recent surge of interest in graphical interfaces (Baecker and Buxton, 1987) and visualisation (McCormick *et al.*, 1987; Frenkel, 1988) within computer science supports this view. Hence, I too believe that the scope for automation of decision-making, using a GIS, does not in itself pose a threat to cartography.

To defend an existing concern is one thing; to disclaim an already thriving new concern just because of its non-traditional form is a different matter. The inclusion of a session on "Large and Small Scale Databases" within the Twenty-Fifth Annual Conference of the BCS at Nottingham suggested that the BCS accepted that spatial databases fell within the remit of cartography. However, some at the Conference forum were of contrary opinion. This stance was partly based on the proposition that the spatial database is not a recent phenomenon; it is limited to providing input to mapping processes and does not merit this new status. This stance, which restricts cartography to small parts of a wider range of activities (see *Figure 1*), will be examined later.

In my opinion, both Guptill and Starr and the traditionalists are mistaken in placing their emphases on the products of cartography rather than on the intellectual content of the discipline. Cartography is not just an art or craft; neither is it just a technology or system for constructing artefacts. It is also a science which seeks to abstract general truths and principles so as to deduce, prescribe or predict the outcome of design methods. No doubt there are other sources of design guidelines and methods but this is not the place to digress into a consideration of the separate focus, aims and practices of cartography as science, technology, system development, art and craft respectively.

If cartography is concerned with the making and use of maps, then it is not just concerned with visual products: it is equally concerned with the processes of mapping, from data collection, transformation and simplification through to symbolisation and with map reading, analysis and interpretation. These intellectual processes are expressed in terms of prevailing technologies and computer-based Information Technology is fast becoming the dominant technology of the day. If we exclude spatial databases from the scope of cartography, it amounts to disclaiming interest in a variety of processes which were traditionally within the province of cartography. Also, there are more substantive reasons for accepting the description of the scope of cartography as defined by Guptill and Starr, even if we reject their focus.

If we did so, we will have to accept that cartography is concerned with two types of maps, namely the *visual map* and the *digital map*. For the spatial database is not just a repository of data, it is a model of spatial reality. This does not undermine the function of the visual map as a model of reality and of data. It merely transfers the data storage and dissemination functions from the visual map to the digital map. The visual map is thus available for the function that it is most suited to, namely the graphic communication of customised information in an holistic form. But, the electronic display map has a further function – it forms part of the user interface to a computerised information system. It not only provides a view of the spatial data, but it may also be used to retrieve and interact with related data by pointing to elements on display (Visvalingam and Kirby, 1984; Visvalingam, 1985). The electronic map has thus become a high-bandwidth, two-way, dynamic communication medium. Thus, modern technology has not just extended the means by which we may produce maps, it is radically changing the way in which we can communicate, explore and understand spatial information through maps. Bertin's *Semiology of Graphics* is still valid but insufficient for expressing the type of communication which occurs through dynamic, two-way maps.

The potential for dynamic, two-way graphic communication can only be fully realised if spatial data can be retrieved within a reasonable response time. Traditional cartography addressed the need for visual modelling of spatial data to facilitate rapid and accurate analysis by the human information processing system. The new cartography recognises the need for appropriate digital models of spatial data to enable rapid and accurate processing by computer technology. This not only requires some appreciation of the capacity and constraints of Information Technology, but it also demands an exposition of spatial data, spatial relationships and related aspatial data in an explicit form. This is already serving to identify and rectify uncertainties regarding the structure and relationship of mappable entities.

Thus, the digital map is not just another conventional databank. It is a structured and succinct model of spatial data, resulting from the sub-discipline of digital mapping. Digital mapping paves the way for exploitation of developments in human-computer interaction for cartographic visualisation and exploration of spatial reality. It is opening up new areas of research for those concerned with skilled map use.

The new cartography should accept that the user's focus is on spatial reality, not on specific tools; both digital and visual maps facilitate the comprehension of this reality through human-computer interaction. If cartographers fail to stake a claim in the processes involved in non-visual mapping, they will be retreating from frontier areas for which others are already contending. The Association of Geographic Information was founded in March 1988. At a well attended meeting of the British Computer Society on 15th

November, 1988, members decided to form a Specialist Group in GIS.

But, where does cartography stand with respect to GIS? Tomlinson Associates (1987, p. 160) stated that "GIS is a unique field with its own set of research problems" and that "GIS is a tool", which they define (on p. 154) as "a digital system for the analysis and manipulation of a full range of geographical data, with subsystems for digitising and other forms of input and for cartography and other forms of display used in the context of decision making. The emphasis is clearly on the analysis and manipulation functions . . ." This definition of GIS implies that GIS are decision-support systems based on the new cartography as defined by Guptill and Starr (1984). Yet, in the above definition Tomlinson Associates portrayed cartography as a subsidiary activity within GIS. This may be because they equate cartography with automated cartography. Tomlinson Associates (1987, p. 154) defined the latter as "the use of computer-based systems for the more efficient production of maps; such systems may replace various forms of manual activity associated with map production, such as scaling, editing, colour separation, symbolisation or typesetting. The systems which have been developed for automated cartography use different data structures and offer a quite different set of functions from those common in geographical information systems, and in general the two types of systems are not highly compatible." They held that "whole areas which are intimately related to GIS, such as spatial analysis and spatial statistics, have no relevance to automatic cartography." They also argued that future GIS development needs "research effort . . . in our understanding of the nature of spatial data itself through such issues as generalisation, accuracy and error" (p. 160–1). But, has this not been the quest of cartography which, incidentally, already teaches the use of inductive statistics in generalisation?

GIS is a computerised tool; in this sense, it has the same relationship to cartography as computerised systems for automated cartography. Automated cartography has been one application of digital cartography (an area of activity within cartography concerned with the use of digital technology) from its very early days. Many of the original aims of automated cartography, some of which were outlined by Tomlinson, were achieved many years ago. The solution of old problems has enabled the subject to shift its focus onto more difficult targets. Indeed, it is now widely accepted that automatic generalisation is one of the many goals of digital cartography, with automatic map interpretation being another.

Tomlinson Associates did not directly compare GIS with the discipline of cartography. Instead, they compared GIS with automated cartography perhaps because they were mainly concerned with commercially exploitable systems based on cartography, computer graphics and/or spatial statistics. The development of GIS does not threaten the progress of cartography any more than it can undermine computer graphics, remote sensing, database technology or statistics, unless cartographers themselves choose to reduce the concerns of the discipline.

GIS is being pushed, and will eventually emerge as, a unique field of activity. If we take away the research and development (R and D) contributions of supporting disciplines then GIS, in its present stage of maturity, appears to be largely concerned with system development and geographic applications rather than with basic research on unique themes. Newby (1988) noted that a considerable amount of basic scientific activity is still required to develop reliable GIS systems with wide ranging applications but that ultimately "GIS remains a methodological tool".

GIS, as decision-support systems, have a focus of activity, namely the specification, design, implementation, prototyping and evaluation of GIS hardware, software, user interfaces, knowledge and data for specific applications. A number of projects are being funded to explore potential applications and gain experience. Feedback in the ESRC Newsletter on GIS (ESRC, 1988) imply a preference for functionally limited systems. As argued by Shand (1987) and Visvalingam (1988 a and b), the requirements of Land Information Systems (LIS) are very different from that of others, for instance that of market analysis systems based on spatial statistics.

GIS systems could be made more accessible and effective by architectures which facilitate product factoring and the development of sub-systems which meet the requirements of specific sets of users (Visvalingam, 1987). All-singing, all-dancing, universal GIS tools are not the most effective environments for all users. But, without a modular supporting framework, the "small is beautiful" approach will lead to a proliferation of *ad hoc* and incompatible GIS developments and a duplication of R and D effort at public expense. Digital cartography can provide the backbone of many GIS, which add application specific modelling and manipulation capabilities to application orientated configurations of components in digital cartography. Attention needs to be focused on this role of digital cartography.

WHAT IS A MAP?

This question was posed by the Education Committee of the BCS at its 1988 Annual Conference open forum on the definition of cartography. It is relatively easy to cite a definition of a map from a reputable dictionary. The problem is that there are too many alternative definitions. Bickmore (1975), for example, quoted a definition dating from 1586 – a map is "a circumstantial account of the state of things". This definition is correct but it is not very useful because it does not explain what a map is to a lay person. We need to examine the ways in which we constrain or illuminate the meaning of map. Four factors appear to be relevant, namely:

(a) the subject of maps
(b) the function of maps
(c) the form of maps
(d) the mapping process

The subject of maps

A map has been defined as the representation in outline form of the surface features of the earth or of the distribution of some phenomenon upon it. The 1973 ICA definition also constrains maps to "representing the Earth or any celestial body". GIS, by their very definition, address the same phenomena. This is because computer-based GIS seek to take advantage of and to process efficiently the large volumes of geographically referenced data, which are becoming increasingly available. Indeed, much of the Chorley Report (DoE, 1987) was concerned with the availability of topographic data and spatial statistics and with their standardisation for purposes of conjoint use.

But, cartographic techniques may be applied to any set of spatial data. For example, scatterplots are point symbol maps of phenomena in measurement, rather than geographic, space and they sometimes employ choropleth or isopleth techniques for displaying clusters and convex hulls respectively. (See Evans (1983) for examples of use of convex hulls). According to Robinson *et al* (1984, p. 3) "This graphic representation of spatial relationships and spatial forms is what we call a map". The Chambers Twentieth Century Dictionary also defined a map as "a representation, a scheme or epitome of the disposition or state of anything". This definition is more consistent with the use made by Bertin (1983) and Tufte (1984) of the language of graphics. If cartography is to take advantage of developments in visualisation technology for exploring and communicating spatial reality through two-way maps, then it should regard maps as depictions of spatial, rather than geographic, phenomena.

Functions of maps

In the past, visual maps were designed to take advantage of the human spatial information processing capabilities. The map model was used for the storage, dissemination and communication of spatial data, forms and relationships for a variety of uses. In digital cartography, the spatial database is the repository of data. Does the transfer of some map functions to the spatial database make the latter a map? Mapping systems, such as SYMAP and SYMVU, used spatial data for generation of maps by computer but we do not regard input data as digital maps.

The term digital map implies a compact, structured, integrated and elegant representation of spatial data and their aspatial attributes in a manner that facilitates rapid inference and retrieval and speedy but error-free update of data. This implies pre-processing and substantial restructuring of input data so that the digital post-processing system may infer spatial forms, relationships and patterns in a way which matches, and if possible surpasses, human information processing capabilities. Digital mapping is concerned with extracting and representing spatial objects and relationships in a complete, explicit and coherent but not redundant form. A video or raster-scanned image may form a good visual map but an inadequate digital map since it can only be used as a backdrop in many applications. Consequently, it is no longer easy to use the form of a display alone to decide whether it may be classed as a visual and/or digital map (see below).

People are superior to computers at spatial pattern recognition and processing. Computers, on the other hand, are more efficient at information retrieval, more consistent in logic processing and more accurate at metrical use and analysis. With respect to function, it appears that the ease with which relevant spatial information (rather than data) may be extracted by the human and/or digital information processing system is an essential quality of maps.

Forms of maps

The 1973 definition of cartography provided examples of various forms of maps, but all these are of visual products; they do not include new forms of maps, such as tactile and digital maps. The definition of maps by their outward forms poses many difficulties. This is particularly so with respect to digital maps but even visual products pose problems.

Visual images include photographs, maps and remote sensed, raster-scanned and video images. Not all photographs are maps, and not all maps are photographic. We could make similar statements about other images. A photograph or a raster/video scanned image would be deemed a map only if it was a copy of the visual map. It is on the basis of its substantive content that we conclude that an image is that of a map. The medium of recording and format of display are not the critical factors. Thus, air photographs are not maps. But, are all true and false colour remote sensed images maps? The separation of the sensing and recording functions does not in itself make such indirect "photographs", recording invisible electromagnetic radiation, maps. When and why do we class some displays of remote sensed data as maps? Both images and maps based on remote sensed data may have the same form, classed as colour raster displays with respect to computer hardware or as high resolution point distributions with respect to mapping techniques. It appears that it is some quality of the information being displayed, and not the raster format or mapping technique, which provides the discriminating factor.

The 1973 ICA definition included three-dimensional models as maps. A solid, three dimensional block often portrays a generalised depiction of the topography and surface features. But, does the inclusion of such solid three-dimensional models also admit all perspective views of digital terrain models, which aspire towards photographic realism, when we reject air photographs as maps?

Increasingly, it appears that a form-based definition of maps is likely to result in inconsistent statements about maps. The principle of equifinality states that many different processes can result in similar forms. Thus, we cannot infer causal factors (here, the definition of a discipline) by examining form alone (here, the products of the discipline). We also need to consider the processes of map making and map use (see below).

With respect to form, what is important is the spatial representation of forms and relationships. Thus, mental models and textual and verbal descriptions, which are essentially linear, are excluded since they do not communicate in holistic forms. But, holistic representations need not be visual.

The mapping process

Robinson *et al* (1983, p. 5) observed that "All maps involve transformations of various kinds" and that "All maps are abstractions of reality. The real world is so intricate and wonderfully complex that merely reducing it or putting a small part of it in image form would make it even more confusing."

Whereas solid object modelling in Computer-Aided Design is concerned with realistic rendering of objects and scenes, communication of spatial reality relies on abstraction and simplification of data into meaningful information (Bertin, 1983). Given the same data, it is possible to generate many different, equally valid views of spatial reality and many other grossly distorted views (Visvalingam and Kirby, 1984). Robinson *et al* (1984) pointed out that each view "will possess certain communication advantages and limitations. The cartographer's task is to explore the ramifications of each mapping possibility and to select the most appropriate for the intended communication." The same may be said of digital mapping. Although, it is possible to arrive at a minimal, theoretically-based conceptual model of spatial reality, one task of the digital cartographer is to define functionally appropriate pragmatic mappings of spatial data (Visvalingam *et al*, 1986).

The transformational view of cartography suggests that all maps, whether visual or digital, demonstrate the effects of transformations. In visual mapping, the processes involved in measurement, analysis and display deliberately or unintentionally bias our view and thus our use of spatial information. In digital mapping, the processes of data capture, re-formatting, modelling and re-structuring (essentially automatic interpretation and generalisation) facilitate the computer's use of spatial information.

The distinguishing feature of maps, both visual and digital, is that they can *focus attention selectively* on regions of space, features, objects and themes in a manner which photographs and minimally processed remote sensed images do not do. It is this feature which makes us call a rectified photograph, to which names, symbols, grid-lines and/or mathematical information have been added, a photomap (ICA, 1973, p. 315) since these additions alter our perception of the image.

CONCLUSION

Definitions represent consensus. This paper has sketched the author's tentative views on the impact of modern developments on cartography and maps. It is therefore inappropriate to conclude with definitions. Instead, the main issues which are likely to have a direct impact on definitions are brought into focus.

* The 1973 ICA definition needs revision because it is vague and does not accommodate modern developments.
* There appears to be general consensus over the *type* of the discipline, namely cartography as an art, science, technology . . .
* There is come question over the *subject* of the discipline. The term, spatial, which is already in common use, is preferable to geographic.
* The *aims* of the subject include the creation of maps to facilitate the comprehension and communication of spatial phenomena for a variety of purposes and the formal study of the processes involved in map-making and map use.
* Maps are *holistic representations* of spatial reality. The map is initially and primarily an *intellectual abstraction* of spatial reality but this must be subsequently communicated, i.e. modelled and coded, in a *form* that exploits the human and/or digital spatial processing capabilities.
* Through use of transformational processes, maps facilitate *selective extraction and emphasis* of relevant spatial information.
* Mapping activities could be directed at visual, digital and/or tactile *products*.
* Digital cartography offers considerable scope for interactive exploration, comprehension and communication of spatial information through maps. It can provide a framework and components for GIS development.

Modern developments encourage different perceptions of the discipline of cartography. Given the escalating interest in GIS, we need to clarify whether cartography is

(a) a separate discipline, providing part of the knowledge base of GIS
(b) a subsidiary activity within GIS
(c) a regressive parent of GIS, which could well inherit, develop and exploit the intellectual wealth and concerns of its parent in an age biased towards the utilitarian, rather than academic, potential of Information Technology.

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