Mapping and Geovisualization

Martin Dodge

> "Like an ant upon a rug, man may know very exactly the nature of the fabric near by, but the general design is beyond his range of vision. In order to reduce the larger patterns of the face of the earth to such proportions that they can be comprehended in a single view, the geographer makes use of a map." (P.E. James, quoted in Raisz 1948: xi)

Introduction

The map is a way we think about the world, a means to make territory, visibly plotting places into existence. Maps are more than representations; they are means to manage resources, to navigate across unfamiliar terrain and as a way to analyse geographical patterns and show the processes shaping the earth's surface. Cartographic practice can be powerful for visualising complex spatial ideas, to contemplate possible futures scenarios, to display past landscapes and imagine realms beyond the physically possible. Maps are practical tools and an essential part of techniques of the government. Maps matter.

Mapping is essentially about making space visible and comprehensible. In philosophical terms the elemental character of maps can be approached as part of a broader interpretation of the importance of the graphic arts and appreciation of our modern 'visual culture'. Vision is the king of senses, the one that matters most. It is the quickest and most direct source of information (light outpaces sound, for example), the widest-ranging (we are seeing millions of years into the past when we look at the stars) and the one that supposedly offers the truth: 'seeing is believing', 'eye-witness evidence', 'the camera never lies'. People without sight are commonly perceived as being profoundly disabled. Vision is therefore a privileged way

of knowing the world, and one that has been closely implicated with the rise of Enlightenment science in the west and the emergence of the modern state. The world was re-ordered from the Renaissance onwards, in part through the shift from an oral culture to one of visual representations, based on creation and exchange of tangible images, most evident in the ascent of the book following Gutenberg's invention of the printing press with movable type in the early 1400s. Subsequent advances in mechanical printing, photographic capture and electronic reproduction further entrenched the power of the visual. This privileged status has only accelerated with the rise of digital media as our primary mode of cultural exchange since the 1990s, such that 'we live in cultures that are increasingly permeated by visual images' (Sturken and Cartwright 2001: 10). Commerce, government and all manner of daily personal communication are transacted through some form of visual media. Much of art and artistic practice involves visual practices and the production of images in some form – it can be quite radical to be a non-visual artist. Indeed, one of the defining characteristics of late modernity of the twenty-first century, it could be argued, is the extent and speed of electronic communication, which results in an unprecedented barrage of visualised images of places and times other than our immediate present.

Our concern here is with the cartographic image, a small but significant part of the vast panoply of 'externalised' and mediated vision available to us today, all purposefully designed to affect how and what we see. Maps are a particularly complex class of visual image – one that has typically required specialised skills to produce and that is deserving of greater scrutiny, especially as map usage grows dramatically with digital media.

Maps as a mode of images are powerful because they are capable of representing reality in a believable way, they hold meaning and they can transmit this meaning reliably to others, being what Bruno Latour (1987) called 'immutable mobiles'. This meaning often has an impact on the recipient, able to affect change in their outlook, thinking and, potentially, future behaviour. Maps do work in changing the world they only seem to be representing.

Maps and Knowledge

Conventionally scholarship and the creation of scientific knowledge has essentially been one of making the most believable images and propagating them so they are accepted as 'truth'. As Latour and Woolgar (1979: 243, original emphasis) documented from their laboratory ethnography: 'scientific activity is not "about nature", it is a fierce fight to *construct* reality'.

Much of what we believe we know of reality, in both art and science, is really a small subset of the possible that can be captured on visual registers, recorded as images and made consumable as graphic representations. The formalised production of geographical knowledge, in particular, has been based primarily on scopic techniques (fieldwork observation, survey measurement, microscopic analysis of samples, and so on). It is therefore unsurprising that the visualised image of space captured in terms of cartography and globes has been commonly regarded as core to the geographer's *modus operandi* for many hundreds of years (Figure 1).

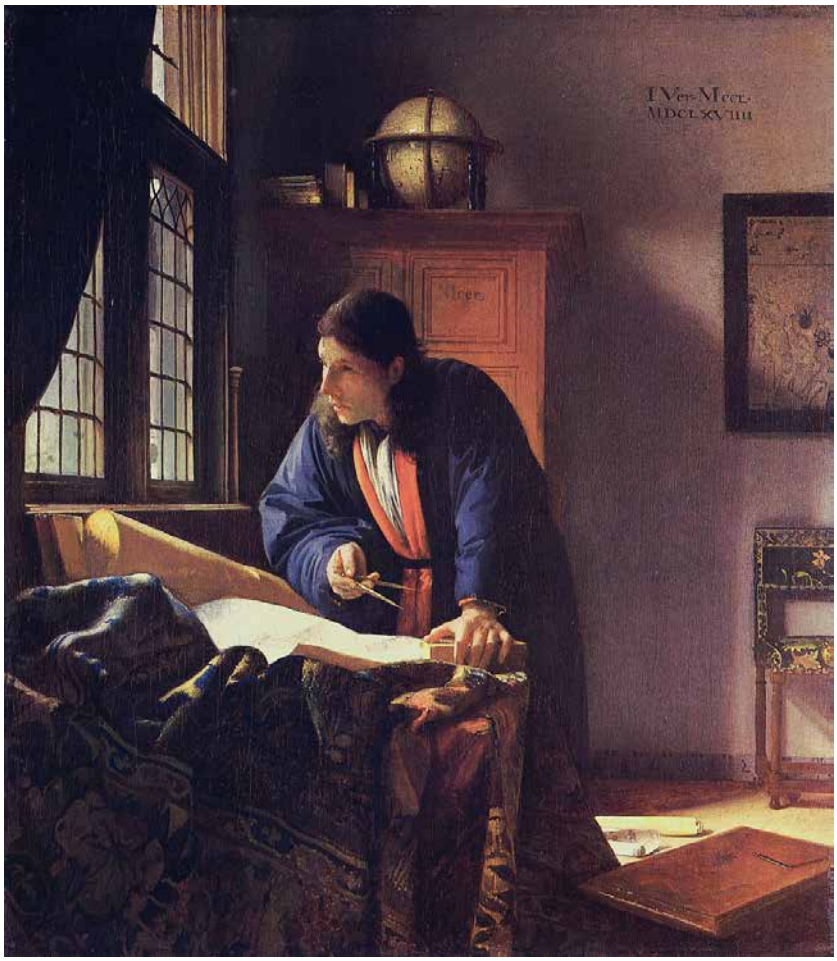

Figure 1. *The Geographer*, by Jan Vermeer, c. 1668–1669. The scene illustrates the practices of geographical science in the 'age of discovery', reliant on visual technologies: topographic maps, navigation charts and terrestrial globes. A framed world map hangs on the wall as a material talisman of the mental work being performed, much like they do in the offices of many academic geographers today. (Oil on canvas, 52 x 45.5 cm. Source: http://en.wikipedia.org/wiki/The_Geographer)

Yet it is evident that in the past few decades cartographic techniques have been much less commonly employed within most human geography scholarship. (As a case in point, the first edition of this textbook contained only two maps within its 350 pages of discursive text.) There are various possible reasons why map use has declined in the discipline: cartography can be perceived as old-fashioned, part of the 'colouring-pencil' cliché of geography as consisting simply of dull description and fact collecting, too tainted with past politics; and, pragmatically, maps are hard to produce well (cf. Dodge and Perkins 2008). While social and cultural geographers have moved away from maps and looked for other ways to analyse data and present their interpretations, cartography does remain an essential representation in many other sub-disciplines of geographical scholarship, and has perhaps gained renewed strength with the rise of digital mapping and GIScience in recent years (see Chapter 8 in this volume). Mapping as a method of inquiry and knowledge creation continues to play a more notable role in the natural science approaches of physical geography because, it could be argued, the map has been regarded as being better suited to quantitative spatial data, useful to structure formally sampled geographic information, to test locational hypotheses and to present results in an authoritative form. This is complimentary to the range of mapping being undertaken beyond conventional geographic scales, and it is particularly potent in 'big data' disciplines such as astronomy, biosciences and particle physics – for example, smashing atoms in the multi-billion dollar Large Hadron Collider at CERN is in some senses a very expensive mapmaking technique, but at phenomenally small scales and in inconceivably short time periods. This is because mapping provides a uniquely powerful means to classify, represent and communicate information about spaces that are too large and too complex to be directly observed. In an instrumental way, the map is a powerful prosthetic enhancement for the scientist's embodied senses: 'like the telescope or microscope, it allows us to see at scales impossible for the naked eye and without moving the physical body over space' (Cosgrove 2003: 137).

Despite the diminished use of maps in human geography research in the last few decades, a real case can be made that cartographic methods are far from old-fashioned and dull, and they can be fruitfully deployed in critical ways to research into all manner of social phenomena and seek to change the production of space. There is a role for maps in applied geographical research designed to impact first and foremost on government policy and communicate with the general public. Many people would expect geographers to express their ideas through mapping, and we are really missing a trick by not exploiting this

expectation to our advantage. The work of human geographer Danny Dorling and colleagues using cartograms that distort space to highlight underlying social structures locked in large datasets has proved how effective mapping can be in showing the extent of inequalities across the globe (browse their web resource, www.worldmapper.org). Part of the reasons Dorling has been successful as one of geography's few 'public intellectuals' has been his willingness to produce maps as a central part of his work (e.g. Dorling and Thomas 2011); as he noted over a decade ago, 'for people who want to change the way we think about the world, changing our maps is often a necessary first step' (Dorling 1998: 287).

Dorling's active use of maps in his influential books and papers also shows how it is possible for human geographers to look beyond the cliché-ridden conventions of the multi-coloured choropleth maps to depict space in a multiplicity of ways. There is scope in human geography for more sophisticated cartographic designs to represent people and places, calling on different visual registers including graffiti, photography, typography, cartoons, sketching, figurative art and computer graphics (e.g. Barnes 2007; Biemann 2002; Harmon 2009; Harzinski 2009; Krygier and Wood 2009; Skupin 2004). While a growing array of simple-to-use software tools and online information display services are providing viable non-technical routes to enable geographers and others to be more creative in making maps and related ways to envision their own data against geography (e.g. www.gapminder.org; www.maptube.org; http://geocommons.com; Figure 2). Moreover, the act of mapping can go even further than creative cartographic design, to challenge preconceptions of what is mappable – the emotional maps created by measuring the stress responses of participants in Christian Nold's (2009) art experiments are a good exemplar.

Figure 2. An unorthodox mapping of the administrative geography of Greater Manchester, with an aesthetic related to typography rather than topographic conventions. The map was automatically rendered using the approximate geographic positioning of place names by the Tagxedo software service (www.tagxedo.com).

What is a Map?

How might we conceptualise the essential nature of cartography? How is a map distinct from other common modes of visual representation? Taking on a functionalist definition from one of the founding textbooks for the science of mapmaking by the émigré Hungarian Erwin Raisz, who became map curator at Harvard University, we might start by asserting that 'A map is, in its primary conception, a conventionalized picture of the Earth's pattern as seen from above' (1948: xi). However, maps are more than this. According to research by Vasiliev et al (1990), who examined multiple definitions of a map given by different dictionaries and scholarly sources, it is possible to identify five core characteristics which mean people will regard a given visual image as being 'a map':

1. Viewer's perspective should be from above, in a sense looking vertically downward. This is the planar viewpoint and is essential to 'proper' cartography;

2. The subject matter should, in some degree, relate to the earth and most typically observable phenomena occurring on the terrestrial surface;

3. There should be an interpretable correspondence between things shown on the map and with locations in reality. ‘When a viewer was able to recognise that an image contained features whose distribution corresponded well with the actual geographic arrangement of the same features on the earth’s surface, the graphic received a higher map-ness score’ (Vasiliev et al 1990: 122);

4. It should be a flat image rather than a three-dimensional one (these are distinct from maps but can be related, such as earth globes, relief models, bird’s-eye views or perspective drawings). The flatness is achieved through the choice of distinct mathematical projection of co-ordinates to transform 3D real space onto a distorted 2D surface;

5. The scale of the image should be in a geographic range, rather than, say, the microscopic or the astronomical. The scale creates a distinct kind of spatial coverage we associate with cartography, and one that is different from, say, the close-up detail of things we would associate with an architectural drawing or a building plan. Typically the scale of features shown will be uniform across the whole map.

Taking these five characteristics together clearly proscribes what counts as a ‘proper-looking map’, yet it still means there are a multitude of kinds of cartography possible, with an array of different geographic scales, subject matters and projections. Part of the creative aspect of cartography is often to play with graphic designs at the boundaries of these five primary ascribed characteristics and to stretch the possibilities of what a map can be. To try to comprehend the diversity of cartography, especially in relation to teaching mapmaking and appropriate design, people have often tried to group maps into a small number of key types. However, accurately and meaningfully classifying the types of map is a tough challenge, in large part because of the tricky examples that lie on the slippery boundaries between ‘definitely-a-map’ and other common representations of space that are used in mapping situations and can have some, but not all, of the properties of ‘proper’ cartography. Indeed, some of the most interesting spatial images sit on the borderlines, such as the point of angular

display and elevation that makes a bird's-eye view akin to but distinct from a strictly planar map, or whether tactile models are cartographic enough to be considered as maps (see Figure 3). Contemporary digital media is also throwing up numerous exemplars that are hard to classify, such as the dynamic driving-view on a satnav display that has usurped the traditional road atlas for many drivers.

It is not possible to neatly to categorise all map-like, spatial images according to a single dimension (e.g. type of phenomena mapped or medium of dissemination). A more useful classification approach has been to create cross-tabulation with several dimensions to group maps. Figure 4 presents such a grid which classifies maps according to their scale from small to large, and then on a second dimension of what we might think of as perceived level-of-detail (i.e. increasing complexity of the representation). Such a typology has utility for determining available map solutions and can help in accounting for how cartography has changed over time. Reading across this classification scheme the meaning of the diagonal axis is especially interesting, because it creates an index of 'realism' of representation running from detailed models in the top left corner down to highly abstracted maps of the whole world in the bottom right.

Figure 3. Is this a map? Or merely map-like? A cast bronze tactile model of the centre of Edinburgh created by David Westby. It is installed as an orientation map and tourist feature outside the National Gallery of Scotland, Edinburgh. (Source: author photograph)

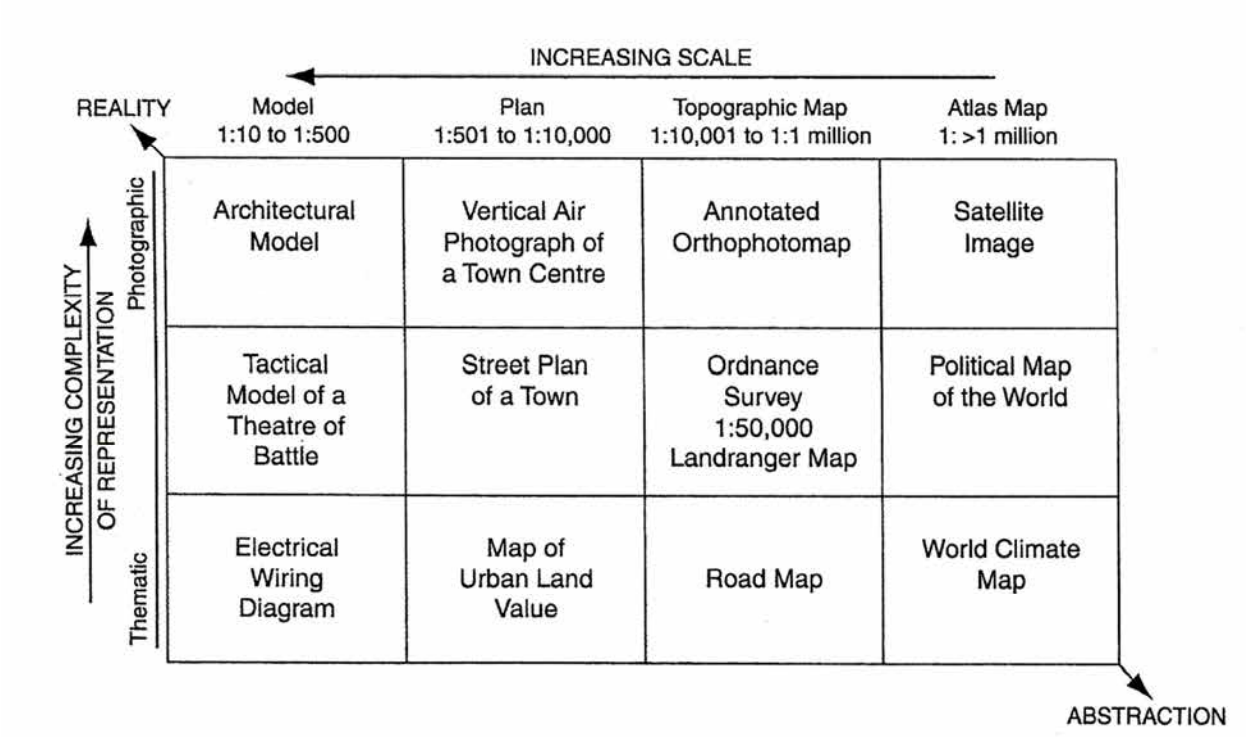

Figure 4. A typology of maps and map-like spatial images arrayed according to the dimensions of scale and realism. (Source: derived from Board 1967: 705)

The notion of cartography being perceived as a 'realistic' representation of the space, yet at the same time essentially a highly abstracted one, has been important in accounting for the power of maps through centuries of their use. However, the inherent 'truth' of abstract maps is now made more uncertain with rising use of digital aerial photography and high-resolution satellite images in the place of conventional cartography (e.g. on the television news). These photographic images are deployed as if they were a map but appear more complex visually, with a richness that is unwittingly accepted as somehow more 'real' – although this degree of realism is misleading as they are not unmediated, 'natural' views of space. Satellite imagery is as artificial as any conventional map, being captured with sensors working on prescribed wavelengths, raw data being digitally processed, warped and resampled, the display colour 'corrected' and so on (cf. Wood 1992, chapter two). The result, one might argue, is actually a supra-nature view of reality: it is what space *should* look like and not what one would actually observe with the naked eye if one were onboard the satellite (Dodge and Perkins 2009).

Another aspect of defining a map in relation to the issue of realism concerns the degree to which cartographic representations must relate to geographic reality. This has long been a debatable point, and one might ask, for example, how do we account for images of fantasy realms that look cartographic but do not have a basis in terrestrial reality (Ekman 2013)? Are these 'proper maps'? And more recently there has been the rise of cartographic representations of the cyberspace, should interactive displays of virtual space be seen as maps (cf. Dodge and Kitchin 2000)? Ultimately, perhaps we might have to default to the maxim: 'a map is a map is a map', where workable categorisation is based simply on the gestalt impression and how it gets enrolled to solve a task. This resonates with the somewhat 'woolly' but now widely accepted definition advanced by two of the leading historians of cartography: 'maps are graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes, or events in the human world' (Harley and Woodward, 1987: xvi). Such a broad definition can encompass the real, the virtual, the fictional and factual.

Another aspect of defining a 'proper map' is to look beyond the finished cartographic artefact image and thinking instead of the *process of mapping*. The conception and construction of any map involves many subjective decisions and much creative practice to abstract reality into a simplified and intelligible visual representation. Mapping as process starts with key choices about what can be meaningfully captured from reality and for what purpose (i.e. able to solve real tasks). There are multiple things (physical objects, people, phenomena, ideas, etc.) that can be geographically located and recorded by some form of coordinate system. Moreover, in the mapping process it is typical that complex objects or phenomena are abstracted to consider them as simple points, lines or areas with only a few knowable characteristics (e.g. individual family homes become residential property represented by square dots, linked to a postcode identifier). While individual items might be simple, there is a major challenge for cartographers involved in positioning and arrangement of many thousands of features, often in close proximity or overlapping in space; just consider a single sheet of a conventional topographic map, like the ones produced by USGS or Ordnance Survey, and the sheer number of distinct features being recorded and displayed legibly to the reader (Figure 5). The national topographic databases maintained by these state agencies or global-scale mapping systems being built by firms like Google can easily contain hundreds of millions of mappable entities.

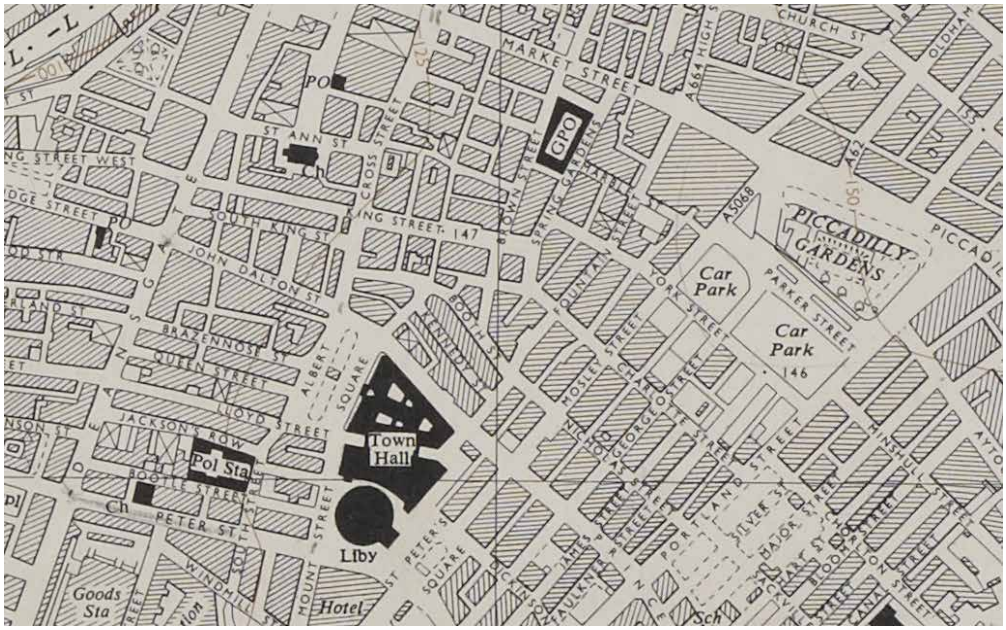

Figure 5. A small portion of a scan of historic Ordnance Survey print map sheet showing Manchester city centre. The complexity of urban reality has obviously been drastically abstracted in the mapping process; nonetheless a large array of different features are cartographically depicted. (Source: author extract from Ordnance Survey 1:10,560 scale map, sheet SJ 89 NW, 1956 printing.)

Despite the huge amount of spatial data being collected, it is apparent that successful mapping of real-world spaces and geographic phenomena involves quite drastic degrees of abstraction – ignoring much, freezing time, simplification of complex features, aggregation of similar features, generalization, classification – to create meaningful patterns that facilitate understanding within a given task domain. There are a panoply of design techniques to do this, particularly in relation to the aggregation and visual generalization of features, and they fill large parts of standard cartography textbooks (e.g. good examples include Dent 1995; Krygier and Wood 2011), but this is also an aspect of cartography in which creative solutions and a degree of artistic licence are required. The power abstraction and the necessity of creative design in the mapping process to elucidate meaningful patterns in complex data is clearly illustrated by some of the 'classics' from the pre-digital era; such as John Snow's 'cholera map' of 1854 (cf. Johnson 2006), Harry Beck's Tube map from the 1930s (cf. Garland 1994) or Charles Joseph Minard's 'Napoleon map' of 1869 (Figure 6).

To consider the last exemplar in a little more detail, Minard's map seems simple at first glance, but is a surprisingly sophisticated charting of the movement of the French army in the Russian campaign of 1812/13, in which over 400,000 soldiers under Napoleon's command

either deserted or died (Figure 6). It is highly abstracted, an efficient representation of a complex, multi-dimensional set of data recording the movements of a massive army over many months and several thousand miles, from the River Niemer in present-day Poland to occupy Moscow, before being forced to retreat again several months later (cf. Friendly 2006). In its entirety Minard's mapping effort offers a plausible cartographic explanation for this complex story of martial mobility across European continent, and according to Tufte (1983: 40), this *Carte Figurative* is 'a narrative graphic of time and space which illustrates how multivariate complexity can be subtly integrated …. so gentle and unobtrusively that viewers are hardly aware that they are looking into a world of four or five dimensions'. As well illustrated by Minard, it is important to bear in mind that the design solutions enacted by cartographers involve subjective choices and do inevitably distort reality, and therefore entail ethical concerns so as not to wilfully deceive the map user (see Monmonier 1996). Some see this subjectivity and distortion as revealing the social interests served by the cartographer and the political consequences flowing out of a particular map to project power in the world (cf. Harley 1989; Wood 1992).

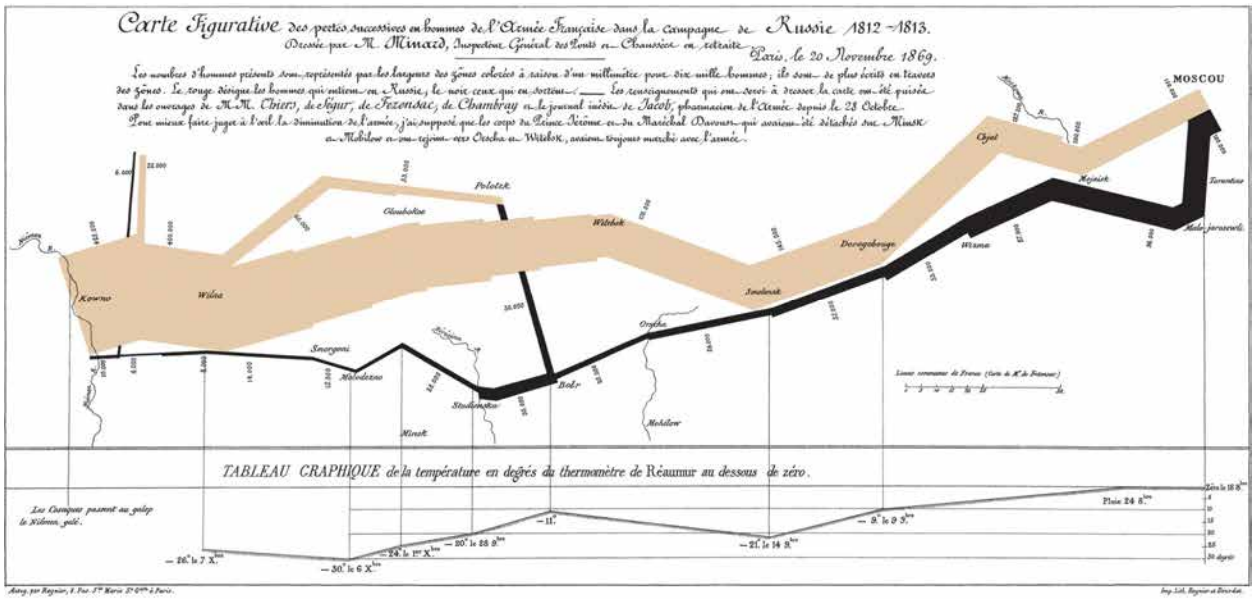

Figure 6. Charles Joseph Minard's now much fêted 1869 flow map of Napoleon's military invasion of Russia. It is a powerful example of the potential of mapping to display complex, multi-dimensional data in a comprehensible fashion. (Source: Cartographia 2008)

Digital Mapping

Maps have traditionally served as paper repositories for spatial data, but they are now more likely to be interactively displayed on screen. In the past decade or so we have determinedly moved past the era of analogue media, dominated by mechanically printed representations, into a situation in which software creates maps from databases and interactive digital models of space are the primary method used to solve everyday tasks. The shift from analogue media to digital interactivity has many implications, including for 'doing geography'. Software and online services are changing how courses are taught, how people learn about geographic phenomena and the way academic research is conducted, even challenging whether embodied fieldwork is still an essential part of being a geographer. One consequence has been an exponential growth in computer-based mapping, with much wider availability of detailed geographic information and innovations in spatial media (for example, the navigable 'streetview' photographs, animated satellite images in the news, map-like models in immersive video games, 3D LiDAR scans). Again, many of these developments are stretching the boundary of what counts as a map. Cheap, powerful computer graphics and higher network bandwidth on mobile devices are also enabling a much more location-centred form of information access, with real-time 'you-are-here' mapping being one of the core aspects of the smartphone's compelling appeal (cf. Meng 2005). Much has rapidly become routine – at least for affluent and digital-savvy people – and increasingly goes unnoticed, simply being part of the on-demand, consumption-orientated society. We come to know more and more about distant places through digital maps and ever more realistic spatial images presented to us on screen, often in our home whilst sitting on the sofa, and made interactive through software. This situation is remarkable in one respect because we've come so quickly to regard it as unremarkable!

Certainly more maps accessible at the touch of a button are now available and many of these seem to be free. Although we should be cautious about the hype around digital media and that it automatically spells a 'revolution' of access. We need to question whether this software mediated world becoming better mapped (cf. Rhind 2000)? Quantity has dramatically increased in the on-demand digital era, but some have grave reservations about the *quality* of so much of the 'free' online mapping (Kent 2008), with its lack of providence and often partial coverage and undocumented accuracy. While digital mapping can be more flexible to use and much more accessible – at least for those with good equipment, the right

software, sufficient broadband network speed and necessary skills – it is also afforded a less reified status than the printed cartography of the past. Free digital maps are now treated as transitory information resources, created in the moment and discarded immediately after use. In some senses, this has devalued cartography as it becomes just another form of ephemeral media, one of the multitude of electronic images that we encounter in our everyday practices. The devalued nature of digital maps, and the seeming unwillingness of the general public to pay for quality products, means there is real concern about the 'death' of professional cartography, with concomitant loss of knowledge and essential skills. (It has become almost impossible to train as a cartographer in the UK, as many colleges and university have stopped offering courses.) There are powerful claims advanced that the digital media 'revolution' is about democratising access to information and that it is profoundly positive that people are being empowered to make their own maps using open source geodata and online services. Yet the availability of 'free' data and purportedly easy-to-use 'point and click' cartography tools is no guarantee that the maps people produce will be appropriate and effective (Haklay 2013). Map-making still takes skill and thought, requiring considerable effort to make *good* maps and intellectual rigour to ensure they are ethically sound representations of space.

It has also been argued, often by critical geographers, that we need to be alert to the politics that lie behind and within, and are enacted through, digital mapping and allied geographic technologies such as GPS receivers, satnavs gadgets and virtual globe software. Since the 1990s a field of 'critical cartography' has shown that all maps – including the most sophisticated computerised cartographies – need to be read not as mirrors of reality but as highly subjective representations of space, as social agents with political implications. It is evident that digital maps have politics, and this can be interrogated in three distinct ways:

- *Politics behind the map*: Here one needs to think about the institutional contexts of those developing, funding and promoting digital mapping technologies. Many of the digital cartographic tools and products we have come to depend upon for everyday tasks arise from military-funded activities or state security agencies, or they are increasingly bound up with the agendas of large and largely unaccountable corporations. For example, many people now take Google Maps wholly for granted as their primary source of geographic information but it is not a neutral source; its representation of space has an institutional setting that stands behind, and directly

influences, what we are shown on screen (Farman 2010). It is possible to discern, at least partially, such institutional agendas through a close decoding of the form and function of digital mapping systems and their ancillary texts (such as marketing literature, patent applications, and so on).

- *Politics within the map*: All maps are necessarily selective, partial models of reality, but critical scholars argue this selectivity is not merely technical but is in fact political. A range of academics, including some human geographers, have sought to expose why certain maps show some things and not others, and how these cartographic choices serve particular interests. Looking at the principal cartography of the state, such as Ordnance Survey's standard 1:50,000 scale Landranger map, one can see official interests stamped upon the representation of the territory. Subaltern interests are often consciously ignored – the concerns of women, children, disabled, non-car drivers, and so on. Many other aspects of reality, including temporal change and much of the social richness of places, which are hard to capture and code with conventional digital maps are consequently 'silenced'. Therefore, the politics within digital maps is important because it effects the larger ontology of geographical knowledge built upon them.

- *Politics through the map*: Lastly, the work of critical scholars highlights the politics of maps by the power they exert on the world they portray. This is a long-standing concern of academics studying the role of cartography and mapmakers in colonial conquest and slavery, or the advances in map grids in the First World War that made artillery shelling much more accurate and thereby aided industrialised slaughter (cf. Schulten 2010; Chasseaud 2002). This continues today with the complicit role of digital mapping in improving the ability of the police to surveil populations and control protest and its contribution to the military's ability to eliminate 'enemies' with precision weapons and remotely controlled drones (Graham 2011). As such it is apparent that maps can enable certain episteme that are often controversial and troubling in democratic societies.

These questions of institutional settings, ontological status of the map and the epistemology of mapping practice continue to be points of interesting and important debate within critical

cartography and the academic GIS community, and human geography more generally. Yet contemporary developments in Geography have looked productively in other directions as well, and one of the most significant developments has come through academic cartographers going beyond the conventional map and enrolling the concept of visualization to open up novel ways to depict the complex, multivalent and intangible nature of space and society.

Geovisualisation

The map as a representational metaphor and main display mode is now key to a whole raft of new interactive visualizations of scientific data. The switch from a static screen presentation to one where the viewer is able to directly control key aspects of the map display underpins the rapid development of spatial technologies including GIS, multimedia atlases and 3D virtual globes. The broader application of sophisticated visualization tools in geography has been evident in the past decade; as such, 'geoviz' has become a significant area for applied research by GIScientists and of relevance to human geographers more generally in how they engage with spatial media (Dykes et al 2010; Thielmann 2010). Geoviz is a significant advancement in mapping and has been claimed to be 'the most important development in cartography since the thematic mapping "revolution" of the early nineteenth century. For map users, [it] represents nothing less than a new way to think spatially' (MacEachren 1995: 460).

Geoviz works by providing graphical ideation to render a place, a phenomenon or a process visible, enabling human's most powerful information-processing abilities – those of spatial cognition associated with our eye–brain vision system – to be directly brought to bear. The act of visualization is a mental process of learning and problem-solving through active engagement with the interactive graphics that make up the map display. It can be contrasted to passive studying of fixed paper maps in that its purpose is primarily to discover unknowns and generate new hypotheses through activity (such as the ability to change scale by zooming in and out), rather than to see what is already known and to confirm a predetermined hypothesis. Proponents argue that effective geoviz can reveal insights that are not apparent with other methods of presentation. As two leading scholars supporting the application of geoviz note: 'The ability to prompt instantaneous changes in maps results not only in a quantitative difference in the number of things a user can make visible, but a qualitative difference in the way users think – and in turn in the way maps function as prompts to

thinking and decision making' (MacEachren and Kraak 1997: 335). Furthermore, to understand the scope of visualization, one must grasp how it has the power to both stir the imagination for exploration and to work instrumentally in solving problems or facilitating the pattern discovery in complex spatial datasets, which are increasingly massive in size.

One way to think about geoviz is to focus on how interactive mapping approaches can be used to do different kinds of work, for example in the various stages of a typical research project. MacEachren (1994) provides a useful conceptual device, the 'cartography cube', to do this (Figure 7), employing three axes to encapsulate the distinctive characteristics of visualization. The first axis covers the scope of the user audience for the geoviz (running from private maps, used only by their maker, through to published, widely disseminated maps for public use); next is the degree to which the map offers 'interaction' in use (ranging from the low interactivity of a point-and-click image up to highly configurable map displays of GIS); the third axis is so-called 'data relations' (a continuum running from revealing unknown patterns to presenting known facts). Distinct types of geoviz practice use can thus be classified and placed within the cartography cube, and four examples are identified here – explore, analyse, synthesize and present (Figure 7). These run roughly from the lower corner of the cube up to the other corner and the diagonal line they form can be thought of as marking the distinction between 'maps to foster *private visual thinking* early in the research process and those to facilitate *public visual communication* of research results' (MacEachren 1994: 3, original emphases).

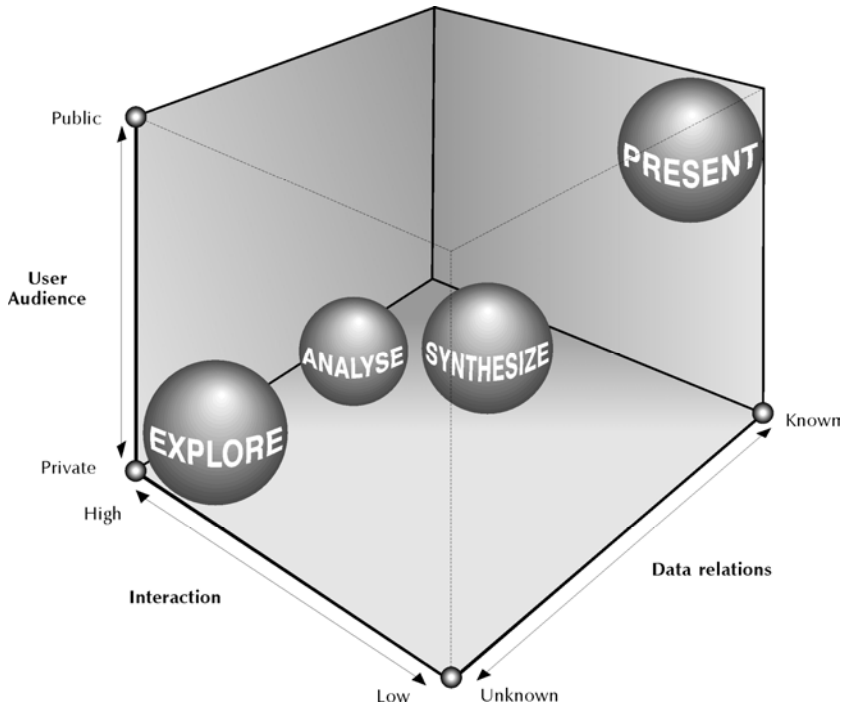

Figure 7. Cartography cube developed by Alan MacEachren as a way to conceptualise the nature of visualization and how mapping can be used in different contexts. (Source: Author's adapted version based on MacEachren 1994: 6)

In the course of a typical academic project, researchers may use maps in a number of different roles, from an initial 'scan' of raw data through to the creation of an 'eye-candy' map for the cover of the final report. Some of the most interesting recent developments in visualization have been in the 'explore' usage – that is, highly interactive private maps for visual thinking. In the 'explore' usage, maps can answer basic 'what is happening here?'-type questions, by giving a visual inventory that can be quickly reviewed for interesting trends and anomalies (seeing the 'holes' in a map can be the best way to spot errors in data collection). The 'analysis' phase of research would use interactive maps to process and classify complex data, breaking it down in the hopes of revealing previously unknown patterns that could not be discerned from looking through the raw data. Here visualization can facilitate discovery of latent patterns, for example through testing for the existence of spatial processes such as hierarchical clustering, small world networks and distance decay functions. The 'synthesis' stage of research often requires evidence to be assembled to support particular hypotheses, and can sometimes in involve shared discussions amongst a team of research around the screen. Towards the end of a research project, it is usually necessary to present results to external audiences, and well-designed maps are an exemplary means of public

communication. A good map can, in a compact visual image, convey a huge amount of data in a legible, aesthetic and comprehensible fashion. Maps are rhetorically powerful ways to dramatize research results (e.g. Figure 8).

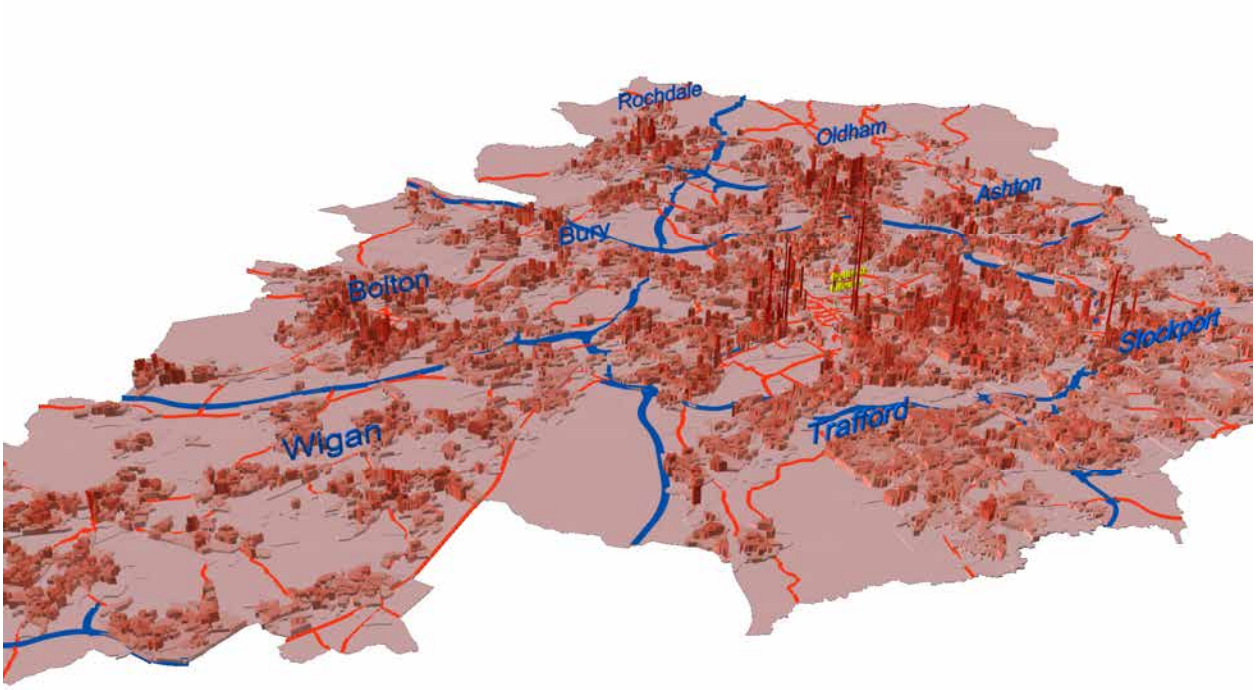

Figure 8. A screenshot of an archetype of geovisualisation, the fly-thru animation of spatial data represented in three-dimensional form. Designed to make sense of the complex social geographies of the 2.5 million people living in the Greater Manchester region, this is a geovisualization of population distribution where density is mapped as 'height' in a stepped-surface map that is rendered in pseudo three-dimensional form and is then animated by flying a virtual camera around it. (Source: Martin Dodge and Karl Hennermann, School of Environment and Development, University of Manchester, based on data from the 2001 Census, Office for Nation Statistics.)

Epilogue

Maps have been an important component in geographers' practice, providing effective means to bring space into comprehensible forms for analysis and interpretation. The *power* of maps comes from the fact that they are both a practical tool of information processing and a compelling form of rhetorical communication. Both involve mapping as process – as a way of thinking space into being. The act of mapping is productive, not just descriptive. More

recent research and technical developments in geoviz clearly show how a process approach to digital mapping can work, essentially, to help people to see the unseen, premised on the simple notion that humans can reason and learn more effectively in an interactive visual environment than when reading textual descriptions or decoding voluminous numerical data.

One might also argue they matter because there is *joy* in the act of making maps. They can be fun, frivolous, vividly artistic, whimsical or simply personal visual narrations of places that matter. Cartographic practice is creative, with some maps made purposefully to satirise and deployed to subvert conventional views of territory propagated via state sanctioned cartography. It seems also that maps are more popular than ever, with heightened curiosity about the nature of cartography in mainstream culture: such interest is evident in games, gadgets, apps, gifts, documentaries, pop-science books and public exhibitions. For example, consider the four-part series on *The Beauty of Maps* (BBC 2010) or Jerry Brotton's engaging *Maps: Power, Plunder and Possession* television documentary. Best-selling books on the intriguing social histories of cartography include Garfield's *On the Map,* Hewitt's biography of the Ordnance Survey and Mike Parker's more personal story of map addition. There have been a raft of public exhibitions, including the 'blockbuster' *Magnificent Maps – Power, Propaganda and Art* held at the British Library in 2010 and, more recently, London Transport Museum's *Mind the Map: Inspiring Art, Design and Cartography* (2012) and *Cartographies of Life & Death: John Snow and Disease Mapping,* held to celebrate the bicentenary of a notable work in spatial epidemiology and abstract statistical mapping capable of changing reality. Thinking more deeply about the meaning of maps is perhaps best done by following Dr Snow's example and doing your own mapping…

References

Barnes A, 2007, ‘Geo/graphic mapping’, *Cultural Geographies* 14: 139–47.

Biemann U, 2002, ‘Remotely sensed: a topography of the global sex trade’, *Feminist Review* 70, 75–88.

Board C, 1967, ‘Maps as models’, in Chorley J, Haggett P (eds.), *Models in Geography* (Methuen: London), 671–725.

Cartographia, 2008, ‘Napoleon’s Invasion of Russia’, *Cartographia blog*, 30 April, <http://cartographia.wordpress.com>

Chasseaud P, 2002, ‘British, French and German mapping and survey on the Western Front in the First World War’, in Doyle P, Bennett M R (eds.), *Fields of Battle: Terrain in Military History* (Springer: Netherlands), 171–204.

Cosgrove D, 2003, ‘Historical perspectives on representing and transferring spatial knowledge’, in Silver M, Balmori D (eds.), *Mapping in the Age of Digital Media*, (Wiley-Academy: London), 128–137.

Dent B, 1995 *Cartography: Thematic Map Design, Fifth Edition* (McGraw-Hill: New York).

Dodge M, Kitchin R, 2000 *Mapping Cyberspace* (Routledge: London).

Dodge M, Perkins C, 2008, ‘Reclaiming the map: British geography and ambivalent cartographic practice’, *Environment and Planning A*, 40(6): 1271–76.

Dodge M, Perkins C, 2009, ‘The ‘view from nowhere’? Spatial politics and cultural significance of high-resolution satellite imagery’, *Geoforum*, 40(4): 497–501.

Dorling D, 1998, “Human cartography: when it is good to map”, *Environment and Planning A*, 30: 277–88.

Dorling D, Thomas B, 2011, *Bankrupt Britain: An Atlas of Social Change* (Policy Press: Bristol).

Dykes J, Andrienko G, Andrienko N, Paelke V, Schiewe J, 2010, 'GeoVisualization and the digital city', *Computers, Environment and Urban Systems*, 34(6): 443–51.

Ekman S, 2013, *Here Be Dragons: Exploring Fantasy Maps and Settings* (Wesleyan University Press: Middletown, CT).

Farman J, 2010, 'Mapping the digital empire: Google Earth and the process of postmodern cartography', *New Media & Society*, 12(6): 869–88.

Friendly M, 2006, 'Visions and re-visions of Charles Joseph Minard', *Journal of Educational Behavioral Statistics*, 27: 31–61.

Garfield S, 2012, *On the Map: Why the world looks the way it does* (Profile Books: London).

Garland K, 1994, *Mr Beck's Underground Map* (Capital Transport Publishing: Middlesex, England).

Graham S, 2011, *Cities Under Siege: The New Military Urbanism* (Verso Books: London).

Haklay M, 2013, 'Neogeography and the delusion of democratisation', *Environment and Planning A*, 45(1): 55–69.

Harley J B, 1989, 'Deconstructing the map', *Cartographica*, 26(2): 1–20.

Harley J B and Woodward D, 1987, *The History of Cartography, Volume 1. Cartography in Prehistoric, Ancient and Medieval Europe and the Mediterranean* (University of Chicago Press: Chicago).

Harmon K, 2009, *The Map as Art: Contemporary Artists Explore Cartography* (Princeton Architectural Press: New York).

Harzinski K, 2009, *From Here To There: A Curious Collection From The Hand Drawn Map Association* (Princeton Architectural Press: New York).

Hewitt R, 2010, *Map of a Nation: A Biography of the Ordnance Survey* (Granta: London).

Johnson S, 2006, *The Ghost Map* (Allen Lane: London).

Kent A J, 2008, ‘Cartographic blandscapes and the new noise: Finding the good view in a topographical mash-up’, *Bulletin of the Society of Cartographers*, 42(1): 29–37.

Krygier J, Wood D, 2009, ‘Ce n’est pas le monde (This is not the world)’, in Dodge M, Kitchin R, Perkins C (eds.), *Rethinking Maps* (Routledge: London), 189–219.

Krygier J, Wood D, 2011, *Making Maps: A Visual Guide to Map Design for GIS, Second Edition* (Guilford Press: New York).

Latour B, 1987, *Science in Action* (Open University Press: Milton Keynes).

Latour B, Woolgar S, 1979, *Laboratory Life: The Social Construction of Scientific Facts* (Sage: London).

MacEachren A M, 1994, ‘Visualization in modern cartography’, in MacEachren A M, Taylor, D R M (eds.), *Visualization in Modern Cartography* (Pergamon Press: Oxford), 1–12.

MacEachren A M, 1995, *How Maps Work: Representation, Visualization, and Design* (Guilford Press: New York).

MacEachren M A, Kraak M-J, 1997, ‘Exploratory cartographic visualization: advancing the agenda’, *Computers & Geosciences*, 23(4): 335–43.

Meng L, 2005, ‘Egocentric design of map-based mobile services’, *The Cartographic Journal*, 42(1): 5–13.

Monmonier M, 1996, *How To Lie With Maps* (University of Chicago Press: Chicago)

Nold C, 2009 *Emotional Cartography: Technologies of the Self* (Ebook available from <http://emotionalcartography.net>).

Parker M, 2009, *Map Addict* (Collins: London).

Raisz E, 1948, *General Cartography, Second Edition* (McGraw-Hill: New York).

Rhind D, 2000, ‘Current shortcomings of global mapping and the creation of a new geographical framework for the world’, *The Geographical Journal*, 166(4): 295–305.

Schulten S, 2010, ‘The cartography of slavery and the authority of statistics’, *Civil War History*, 56(1): 5–32.

Skupin A, 2004, ‘The world of geography: Visualizing a knowledge domain with cartographic means’, *Proceedings of the National Academy of Sciences of the United States of America*, 101(Supplement 1), 5274–78.

Sturken M, Cartwright L, 2001, *Practices of Looking: An Introduction to Visual Culture* (OUP: Oxford).

Thielmann T, 2010, ‘Locative media and mediated localities’, *Aether: The Journal of Media Geography*, 5, <http://geogdata.csun.edu/~aether/>

Tufte E R, 1983, *The Visual Display of Quantitative Information* (Graphics Press: Cheshire, CT).

Vasiliev I, Freundschuh S, Mark D M, Theisen G D, McAvoy J, 1990, ‘What is a map?’, *Cartographic Journal*, 27: 119–23.

Wood D, 1992, *The Power of Maps* (Guilford Press: New York).