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From mathematical to post-representational understandings of cartography: Forty years of mapping theory and praxis in *Progress in Human Geography*

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Progress in Human Geography has been a key conduit for the advancement of cartographic theory and practice over the past 40 years, publishing both original papers and progress reports that discuss leading-edge cartographic thought, technological developments, and empirical works of the time. In total, 36 papers with an explicit focus on cartography have been published in the journal, 17 of which are reproduced in this virtual issue. Collectively, the papers provide a fascinating historiography, told through multiple voices, into the development of cartographic theory and praxis since the early 1970s. This period has been one of great theoretical and technical ferment, with several conceptual perspectives being developed and employed in an effort to better understand maps and mapping, and rapid technological developments transforming the ways in which maps were created and employed, including digital cartography, geographic information systems, and the geoweb.

Keith Bassett's 1972 paper in *Progress in Geography* (which split to become *Progress in Human Geography* and *Progress in Physical Geography* in 1977) is a detailed overview of mathematical methods for map analysis, specifically forms of map generalization, comparison and classification, including surface decomposition, identifying scalar patterns in surface components, descriptive geometry, areal data aggregation, and trend analysis. In being able to quantitatively chart the spatial relationships of mapped data, Bassett posited that it was possible to identify the nature of geographic processes. In other words, maps not only represented spatial relationships, but could be analysed using mathematical techniques such as geometry, topology and spatial statistics to explain them. This was followed in 1977 by Boots and Getis's paper on a probability model approach to analysing map pattern analysis, which advocated an analytical approach aimed at 'identifying the processes considered responsible for the particular form of the phenomena shown on the map' (p. 264). In both papers, rather than simply being outputs that describe the world, maps and the spatial data they convey

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are viewed as inputs to explanatory spatial models. Such an understanding dovetailed with those being expressed during the quantitative revolution, which had been occurring in geography over the previous 20 years, that argued that geographic processes and systems could be explained using scientific methods commonly employed in the natural and physical sciences.

Bassett's and Boots and Getis's papers were followed by the first of four cartography progress reports written by Christopher Board (1977, 1979, 1980, 1982). The first report focused on the recent publication of Robinson and Petchenik's book, *The Nature of Maps* (1976), with its challenge to the conventional cartographic literature of the time, which was broadly divided into two camps: how to produce maps, and maps as sources of geographic information. Board notes that Robinson and Petchenik take a different, more conceptual approach, drawing on philosophy, psychology and education, tackling basic but tricky ontological questions such as 'what is a map?', setting in progress a debate that continues to this day (and which other papers in this virtual issue address, notably Del Casino and Hanna, 2000; Crampton, 2001; Perkins, 2003; Kitchin and Dodge, 2007, Gerlach, 2014).

Unlike Bassett's view of the map as a source of spatial data, Robinson and Petchenik argue that it is a communication system designed to convey spatial relationships. Others at the time were developing similar ideas, and the report goes on to discuss research concerning map reading and map effectiveness. In his second report, Board (1979, this issue) turns his attention to cognition and cartography, and the burgeoning behavioural geography and environmental psychology research in the 1970s that focused on the psychological processes underpinning how people read, engage with and remember maps, and translate them into action, and how maps might be more effectively designed to facilitate such processes, including research on the perception of symbols. Board's third report (1980) is an extended book review of Hopkin and Taylor (1979), focusing on human factors in map design, and his fourth (1982) is an overarching review of several sub-topics including teaching mapwork, mental maps, map reading, and computer-assisted cartography.

After the first of Board's reports, another form of cartographic research was published in the journal, detailing the history of cartography in China from 221BC to the 1970s. Chen Cheng-siang's paper charts the evolution of Chinese cartography and the development of mapping principles through a number of dynasties, including a comparison of early forms with those being developed in Ancient Greece. The paper illustrates how the conceptual and technical underpinnings of cartography have long been contested and in evolution. Although the argument is underdeveloped, the paper makes the case that cartography as a discipline is highly Western-centric, with the history of cartography essentially being that of European cartography, making the case that, given China's and other civilizations' long history of mapmaking, cartographic history 'must be written anew' (p. 118).

In the early 1980s, Mark Monmonier wrote three cartographic progress reports, the first of which is included in this virtual issue. In all three cases, he turns the lens away from cartographic theory, arguing that cartography was maturing, becoming 'unencumbered by the prevailing communication paradigm of the 1970s' which 'promised more than can be delivered' (Monmonier, 1982: 441). Instead, he focuses attention on the rapid technological changes taking place at the time, with the development of computer-assisted cartography and early forms of geographical information systems, and what these meant for the publication and use of geographic information (pre-figuring the internet) and for policy-making (Monmonier, 1982, 1983). Here, the focus is largely pragmatic and instrumental, rather than conceptual, forsaking debates concerning how best to make sense of

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maps to consider practical issues of how they could be made, transmitted and used in a new technological era. In the final report (1984), he also details recent work on the history of cartography and its links with policy-making.

Taking over from Monmonier, between 1985 and 1992 Michael Blakemore wrote six progress reports. The first four reports paired cartography with geographical information systems, reflecting the trend identified by Monmonier, as cartographic practice became increasingly computerized and subsumed within emerging GIScience debates, with maps becoming viewed 'as but a part of an overall set of representational techniques' (1985: 566). In his first report, Blakemore (1985) noted that teaching and training had yet to catch up with the rapidly changing technological toolkits, detailed the large expansion in the geographic information base, discussed issues concerning the handling of vector and raster data, and considered what GIS meant for traditional cartography. His second report (1986, this issue) examined a perceived disjuncture between academic cartography and the everyday production and use of maps, the testing of cartographic ability, and the extent to which cartography is a science or art. The third report (1987) discussed the privacy and political implications of spatial and mapped data, national digital cartographic databases, the development of GIS techniques and data structures, and the relative merits of different systems. The fourth report (1988) examined the relationship between academia, government and industry with respect to GIS in the UK and the USA and the blurred relationship between digital cartography and GIS, and noted the first volume of the *History of Cartography* and some of the debates emerging from its publication.

By the fifth and sixth reports, GIS had been allocated its own set of progress reports. Interestingly, however, rather than focus the cartography reports on traditional cartographic research, such was the influence of GIS on the cartographic sphere that Blakemore recasts cartography as relating 'very much to the geographic information that will be utilized within a GIS' (1990: 101; this issue). In effect, cartography is reduced to the handling of spatial data that forms the input to GIS. Within this context he examined the cultural context of digital cartography, attempts to automate cartographic procedures using artificial intelligence, and the quality of spatial data. In his final report, Blakemore (1992) makes reference to emerging critiques of GIS, its lack of a theoretical base and implicit positivism, the dearth of spatial analysis tools, and the marginalization of fundamental cartographic problems in favour of data structures and database technologies, as well as providing a state of play review with respect to technologies and human and organizational factors.

In the first of three reports, David Unwin (1994, this issue) brought cartography and GIS back together again, and discussed them in conjunction with scientific visualization (his subsequent two reports focused exclusively on GIS). Just as cartography provides a means of capturing and representing a complex world, Unwin argues that scientific visualization and visual analytics have become vital tools in science to assimilate and make sense of flows of complex data. From this perspective, mapping can be used as a 'fundamental scientific tool to establish where things are at all scales from the subatomic to the galactic' (p. 517). Drawing on Bertin (1983), a case is made that good maps are, like mathematics and graphics, monosemic and non-ambiguous because each symbol is known prior to observation, rather than being polysemic, like natural language and figurative imagery, wherein the 'meaning of each symbol is deduced following observation of the collection of signs and thus is capable of several different interpretations' (p. 518). Moreover, it is contended that humans can make sense of very complex graphics without the needed for too much generalization. In other words,

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cartography has the same characteristics as scientific visualizations and can be treated and used in the same ways as analytic tools. Further, scientific visualizations enable entirely new forms of map display which extend the number of available graphic variables (plan, size, shape, value, orientation, hue, texture) to include focus, realism, interaction, projection, time and sound.

At the turn of the new millennium, Alan MacEachren (1998, 2000, 2001) wrote three cartography and GIS reports. The first examined the rapid development of the World Wide Web, invented less than a decade previously, and the development of mapping resources and online mapping tools (this issue). He correctly predicted a number of ways in which the internet was set to radically transform mapping practices and also map theory by prefiguring the geoweb. His second report considers how cartography and GIS, especially those online, can facilitate collaboration and collective decision-making between various stakeholders in managing projects. He extends this in his third report to consider how technological advances facilitate same time/different place geocollaboration between stakeholders.

Two other important cartography papers were published in the journal at the same time as MacEachren's reports. However, rather than focus on the technologies that were transforming cartographic practice, the papers by Del Casino and Hanna (2000) and Crampton (2001) are notable for pushing the theoretical envelope. Although not widely recognized as such, Del Casino and Hanna's paper was one of the first papers to explicitly argue for a post-representational cartography that understood maps as ongoing processes rather than representational products. Using tourist maps as an example, they argue that the 'moment of map production is no longer determinant' (p. 24) with space, identities and maps being co-created through their use; that mapping is intertextual and contextual and meanings are never fixed. Thus, understanding maps from a critical cartography perspective requires more than simply deconstructing their creation and associated power dynamics, but also how they are used in practice to produce identities and spaces. Crampton's paper examines the notion of maps as social constructions, extending the critical work of Brian Harley (1989) to explore the epistemic break between maps as a communication system and maps as sites of power-knowledge. He does so by drawing on the ideas of Michel Foucault and applying them to geographical visualizations and forms of online distributed mapping. Like Del Casino and Hanna, Crampton explores the notion of an individual becoming a cartographer in online media, rather than simply being a consumer of a constructed product. Both papers helped to open up new ways of thinking about maps by embracing ideas from critical human geography and social theory.

Such thinking was taken up by Chris Perkins in his three cartography reports (2002, 2003, 2004). In his first report, Perkins examined developments in tactile mapping for people with visual impairments. In the second and third reports, however, he focuses on cartographic theory. The second report charts the position of maps in human geography of the time, arguing that how maps are perceived had divided into two camps. On the one side, maps had either largely disappeared as an analytic tool used by human geographers following the cultural turn or were the focus of analysis, understood as agents of power and therefore suspect, and on the other, maps were technical communicative devices with research focusing on how they worked in practice. His third report (this issue), rather than charting the development of wider cartographic debates, sets out an argument about how maps have been marginalized within the discipline in favour of the discursive power of words; how the rhetorical power of maps has become stultified by critical theory. Ironically, he notes that his paper is the

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first cartography paper in the journal in over 20 years to include a map. With a nod towards non-representational theory, Perkins explores examining mapping practices as performative using ethnographic methods.

In 2005, Mark Monmonier once again took on the role of writing three cartography reports. These he steers away from Perkins's overviews of cartography's encounters with social theory, back towards more technical undertakings. Each of his reports is themed, drawing together recent literature on map projections, access to cartographic information, and cartographic representation in the wake of 9/11 (2005); handling uncertainty, the role of maps in policy and public opinion, and dynamic mapping (2006); and cybercartography (multi-media forms of cartography accessible online), history of cartography, and public participation and GIS (2007).

In the final year of Monmonier's reports, the focus once more swung back round onto cartographic theory. Building on the work of Del Casino and Hanna (2000, this issue), Kitchin and Dodge (2007, this issue) questioned the ontological security of maps and made the case for rethinking cartography as a processual, rather than representational, science. They put forward the notion that it was productive to conceive of cartography as ontogenetic, that is, always in the process of making place. Drawing on the concepts of transduction and technicity, they contended that maps are of-the-moment, brought into being through practices (embodied, social, technical); that maps are never fully formed and their work is never complete – they are always *mappings*, that is, spatial practices enacted to solve relational problems (e.g. how best to create a spatial representation, how to understand a spatial distribution, how to get between A and B, and so on). Such an ontological reworking, they argued, opened the way for a new epistemology that focused on how maps were created and used in practice, rather than being fixated on the technical rules of production and politics of the artefact.

This paper was followed by a fascinating set of three reports written by Jeremy Crampton that blend together an overview of the rapid technological changes taking place with respect to the geoweb and spatial technologies with evolving cartographic theory able to make sense of them. In his first report (2009a, this issue), he outlined what he terms 'maps 2.0': the way in which maps are becoming more interactive, social and open in their creation through the crowdsourcing of cartographic information and use of open source licensing, but also in their use through geocollaboration, sharing and commenting. In the final section of the paper he considered whether such developments are leading to a deprofessionalization or reprofessionalization of cartography – a question on which the jury is still out (see Dodge and Kitchin, 2013). In his second report (2009b), he explored maps as performative, participatory and political, examining the intersection of maps with art and psychogeographies, and with forms of protest and political participation. The final report (2011) examined cartographic calculations of territory and how maps are enrolled in various ways in political manoeuvres to claim, survey and police people and places.

The first of Sébastien Caquard's cartography reports (2013, this issue) focuses on maps as storytelling devices and their relationship to narratives and metanarratives, particularly with respect to the geoweb. Drawing on literature in film studies, literary studies, visual arts, computer science and communication, he makes a distinction between story maps (that embody our personal experiences of an environment) and grid maps (disembodied, scientific abstractions), arguing that new online mapping services facilitate the former by enabling annotations and interactions and thus enabling new stories to be told about places. Moreover, narratives such as stories and letters can be spatialized, with places and paths within them plotted onto maps and shared. In his second report (2014), Caquard details how geosocial

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media is enabling the collaborative and collective mapping of the world, facilitating community mapping, focusing on the production of indigenous cartographies, and making possible the very fast mapping of places affected by crisis events – and how these developments challenge traditional state and corporate mapping regimes.

The two most recent cartography papers published in the journal both further develop the notion of post-representational mapping. Joe Gerlach (2014, this issue) makes the case for examining cartography through a non-representational lens that prioritizes a focus on vernacular mapping practices (non-statist, extra-institutional, participatory), wherein maps are understood as being more-than-artifacts which emerge through processes and performances and have affective qualities and produce diverse micro-politics. Tania Rossetto (2014, this issue) seeks to bring into productive dialogue cartography and literary criticism, arguing that the notion of cognitive mapping in literary studies might enable some conciliation between cognitive and post-representational cartography, and that the ideas of post-representational cartography would help make sense of maps in literature.

As this short introduction highlights, all of the main theoretical and technological developments and debates that have taken place in cartography over the past 40 years have been captured in the journal's pages. Indeed, the papers and reports provide a rich introduction to the wide diversity of cartographic ideas and research taking place in geography, Cartography, GIS, and a plethora of other disciplines, and their collective bibliographies, detail a comprehensive roadmap of relevant literatures. Given the plurality and vibrancy of present debates, and the fast changing nature of geo-technological developments, there's little doubt that the journal will continue to be an essential resource for anyone interested in maps and mapping.

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