Conceptual Problems in the History of Cartography: A Manifesto for the Study of Early Mapmaking

We recognize yet another role for maps. In the solution of certain problems for which the mathematics, however elegantly stated, is intractable, graphical solutions are possible. This is especially true with regard to "existence theorems". There are many cases in which the graphical solution to a spatial problem turns out to be a map in the full geographical sense of the term, "map." ***Thus a map is a solution to the problem.***

–William Warntz, Geographic Regionalization and Extended Venn Diagrams

[Cartography] is the theory of multiplicities, each of which is composed of actual and virtual elements. Purely actual objects do not exist. Every actual is surrounded by a cloud of virtual images.

--Giles Deleuze, The Actual and the Virtual, Dialogues III

It is obvious that an imagined world, however different it may be from the real one, must have something—a form in common with it.

--Ludwig Wittgenstein, Tractatus Logico-philosophicus

The following outline will give all of you some idea of the conceptual problems that we are going to face in this class as we explore the earliest development of scientific cartography in the West. You will most likely find that much of what appears here is very different from what you may have encountered in courses like this in the past. This is purposeful, as it is my intention to take an approach to this material that uses the theoretical tools developed by modern historians and philosophers of science, rather than that employed typically by more traditional historians of cartography.

I always think of cartography, at least in its western incarnation, as a theory of possible worlds[1]; a place where particular kinds of counter-factual simulations have been carried out, this is especially true when one considers mapmaking's modern digital form which has revolutionized the discipline. My own sense is that the actual maps that exist are but a tiny subset of the theoretical maps that could exist. These real maps are products of a very small number of trajectories through cartographic space, each with its own unique place in this mathematical construction. Every real map is surrounded by a tiny cluster of real or unreal neighbors who are its ancestors and descendants. Abstracting and simulating actual and possible worlds is the purpose of cartographic and geographic analysis.

1. Structure and Geometry

Understanding the form of early cartography and how it changed with new geographical discoveries of the early modern period requires a deep knowledge of geometry and the advances in the mathematical sciences that made the structural changes in the form of early maps possible. The mathematical sciences that form the foundation of both early and modern cartography were in constant development from the earliest periods of Ptolemy and into the Renaissance and beyond.

[1] For more on this deep philosophical and modal concept see David Lewis (1986), On *the plurality of Worlds*, (London: Wiley-Blackwell), where he puts forward a complex theory of modal realism.

We will examine closely the necessary Euclidean geometry needed to understand early map projections and the geometric constructions that are possible within a system of geometry which utilized only the pencil, straight-edge and circle drawing compass[2]. This kind of hands-on activity will help us to better understand the expansion of the Ptolemaic forms of mapping, and how new projections were invented. We will treat map projections in the most general way possible, studying them as geometric coordinate transformations and searching for invariants and homologies[3]. This way of looking at map projections will allow us to look deeply into some of the central technical problems facing ancient, medieval and Renaissance cartographers[4].

Essential to understanding Ptolemy and later cartography will be the concept of "developable surface" and the classic problems associated with the shape of the earth[5]. We will extend our time frame past 1550 for this discussion bringing in some of the critical ideas first outlined by Newton and the important mathematical discovery of "conformality" and "surface embedding" outlined in detail by Gauss[6]. This background will lead us naturally to the larger and more general mathematical properties of intrinsic and extrinsic surface geometry.

2. Transmission and Information Networks

One of the central problematics found in research of early cartography is the question of information flow. How did geographic information circulate in the late Roman period through the Middle Ages and into the Renaissance?

We will examine questions related to information networks and discuss the structural form of some of these touching on the deep question of what their form can tell us about how information moved. We will talk about random, small worlds, clustering, and other types of networks in order give us some sense of the difficult problem of information flow during this early period. Considering questions of how to model these networks will help us penetrate in to the cultural reasons for their form and we will look to modern information networks for analogies[7].

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[2] For a good survey of the necessary Euclidean geometry see Ian Mueller*, Philosophy of Mathematics and Deductive Structure in Euclid's Elements* (New York: Dover Press, 2006).

[3] The categories of geometry are a fascinating field and full of philosophically deep inquiry. For more on this see the opening chapters of Tim Maudlin's*, Philosophy of Physics: Space and Time* (Princeton: Princeton University Press, 2012) 1-54.

[4] The best current edition in English of Ptolemy's theoretical geography is found in J. Lennart Berggren and Alexander Jones'*, Ptolemy's Geography: An Annotated Translation of the Theoretical Chapters*, (Princeton: Princeton University Press, 2000).

[5] An outstanding survey of the problem of the earth's shape in the Early Modern period can be found in John L. Greenberg's, *The Problem of the Earth's Shape form Newton to Clairaut: the Rise of Mathematical Science in 18th Century Paris* (Cambridge: Cambridge University Press, 2010)

[6] Perhaps the most important theoretical work in the history of cartographic science is Gauss' *General Investigations of Curved Surfaces*, whose Latin title *Disquisitiones generals circa superficies curvas* was published in 1827 and in which he develops the critical mathematical concepts of intrinsic and extrinsic curvature and sets the stage for a general theory of developable surfaces that is so critical to modern conformal mapping.

[7] Spatial networks and their structure are a critical part of the modern study of transmission and connectivity in the social sphere. For good introductions to the general theory see, Marc Barthelemy, "Spatial Networks," *Physics Reports* 499 (2011) 1-101 and Sergy N. Dorogovtsev, *Lectures on Complex Networks*, Oxford Master Series in Statistical, Computational and Theoretical Physics (Oxford: Oxford University Press, 2010)

A related and still active area of current research is the question of the manuscript tradition of Ptolemy. Touching on this difficult question will give us some insight into how difficult research into the earliest kinds of scientific cartography is with currently available evidence and help us come to terms with the limits of what we can actually know.

3. Information Order and Assemblage[8]

This concept, borrowed here from historians of science, asks the question of what kind of information was needed for an early cartographer to begin making a map. What did he need to pull together to construct a particular vision of the geographic outlines of the world from both a technical and informational point of view? We will explore this question through examples and by looking at how the information (data if you like) needed to construct maps like the 1516 Carta Marina and some earlier Roman examples was brought together in one place and assembled[9].

4. Epistemological Concerns

Central to any investigation of early science are a series of questions which are all too often ignored by historians of cartography, and that relate to how information was categorized and how it was perceived within disciplinary frameworks of the period[10]. How did cartography fit in with other technical pursuits and how did it function as an ordering of various kinds of knowledge? What role did the different forms of cartographic expression, from cosmographies and Portolan charts, to land surveys, play in the highly categorized knowledge regimes of the ancient, medieval and Renaissance world?

Related to these categorical and cultural questions are more logical questions relating to evidence evaluation. How was geographic data evaluated for its "truth" and "accuracy"? Can we even talk in any coherent way about the notions of accuracy in early cartography?

Considering these philosophical problems will help us develop a theory of the instrumental nature of early cartography and force us to use more modern conceptual ideas, such as notions of theoretical under-determination, and "saving the phenomenon," to come to terms with mapmaking's social function in its earliest years.

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[8] Perhaps the best work on this subject is currently being done by Simon Schaffer of the University of Cambridge. His work on the information order of Newton' *Prinipia* is a fine example of both method and presentation. For his 2008 Hans Rausing Lecture, "The Information Order of Isaac Newton's Principia Mathematica," go to http://www.vethist.idehist.uu.se/pdf/schaffer.pdf .

[9] For a detailed treatment of this see John Hessler and Chet Van Duzer, *Seeing the World Anew: the radical vision of Martin Waldseemuller's 1507 and 1516 World Maps* (Washington, DC: Library of Congress, 2012) and John Hessler, *A Renaissance Globemaker's Toolbox: Johannes Schoner and the Birth of Modern Science, 1475-1550* (London: Giles, Ltd and the Library of Congress, 2013)

[10] The epistemology of early cartography and the mixed and applied sciences is a difficult area of inquiry. For an example of current trends see, Alexander Jones, "Ptolemy's Geography: Mapmaking and the Scientific Enterprise," in *Ancient Perspectives: Maps and Their Place in Mesopotamia, Egypt, Greece and Rome* (Chicago: University of Chicago Press, 2012) and Richard Westfall, "Background to the Mathematization of Nature," in *Isaac Newton's Natural Philosophy* (Cambridge, MA: MIT Press, 2001).

5. Mereotopology

Whatever exists in a space or has spatial extent can in principal be mapped. The roots of all cartography grow out of this cognitive realization. We will look at some of the formalized theories of spatial cognition in relation to early cartography and discuss certain distinctions that arise when trying to define cartographic concepts[11]. Fuzzy and vague conceptual questions such as, "what is a boundary?" and "what kind of objects can be mapped[12]," abound in early cartography and bring us into contact with the profound problem of visualization and diagrammatic thinking. Why map at all? Why try to bring onto a flat plane an abstraction of three-dimensional space? What is the cognitive power of a diagram and how does it claim its authority?

6. Mimesis/Usability[13]

One of the most interesting things about cartography is its visual form. It is certainly this fact that has led to its long history; a history that continues to develop and change even today. The visual form of early cartography tries to convey something to its onlookers and its form of representation was selected for a purpose[14]. A map's form of expression (what it shows and what it excludes) gives us some insight into the seldom considered fourth dimension of cartography; that found in the minds of the cartographers themselves. We will spend a great deal of time discussing the expressiveness of mapmaking and the mimetic qualities of early cartography, as we seek a better understanding of the cultural and geographical spaces inhabited by early mapmakers.

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[11] For a good introduction to the rapidly expanding research in Mereotopology see Roberto Casati and Achille C. Varzi, *Parts and Places: The Structures of Spatial Representation* (Cambridge, MA: MIT Press, 2003). This is one of the most critical areas for ontological research into cartographic and spatial representation in modern GIS. Interested readers should look into, Biacino L., and Gerla G., 1991, "Connection Structures," *Notre Dame Journal of Formal Logic* 32: 242-47; Clarke, Bowman, 1981, "A calculus of individuals based on 'connection'," *Notre Dame Journal of Formal Logic* 22: 204-18 ; ------, 1985, "Individuals and Points," *Notre Dame Journal of Formal Logic* 26: 61-75; Cohn, A. G., and Varzi, A. C., 2003, "Mereotopological Connection," *Journal of Philosophical Logic* 32: 357-90; Forrest, Peter, 1996, "From Ontology to Topology in the Theory of Regions," *The Monist* 79: 34-50; Gerla, G., 1995, "Pointless Geometries," in Buekenhout, F., Kantor, W. (eds*), Handbook of incidence geometry: buildings and foundations.* North-Holland: 1015-31; Roeper, Peter, 1997, "Region-Based Topology*," Journal of Philosophical Logic* 26: 251-309; Smith, Barry, 1996, "Mereotopology: A Theory of Parts and Boundaries," *Data and Knowledge Engineering* 20: 287-303; ------, 1997, "Boundaries: An Essay in Mereotopology" in Hahn, L., ed., *The Philosophy of Roderick Chisholm*. Open Court: 534-61; Varzi, A. C., 1996, "Parts, wholes, and part-whole relations: the prospects of mereotopology*," Data and Knowledge Engineering*, 20: 259-286; ------, 1998, "Basic Problems of Mereotopology," in Guarino, N., ed., *Formal Ontology in Information Systems*. Amsterdam: IOS Press, 29-38; ------, 2007, "Spatial Reasoning and Ontology: Parts, Wholes, and Locations" in Aiello, M. et al., eds., *Handbook of Spatial Logics*. Springer-Verlag: 945-1038.

[12] Barry Smith and David M. Mark, "Do Mountains Exist? Towards an Ontology of Landforms," *Environment and Planning B: Planning and Design* 30 (2003) 411-427.

[13] Philosophical treatments of this important topic are becoming more common in recent years. For the best summary of current ideas see Bas Van Fraasen*, Scientific Representation: Paradoxes of Perspective* (Oxford: Oxford University Press, 2010) and his *The Scientific Image* (Oxford: Oxford University Press, 1980).

[14] In recent years studies of diagrammatic thinking and the epistemological import of visualization has become an active area of research. For more see Jesse Norman*, After Euclid: Visual Reasoning and the Epistemology of Diagrams* (Stanford: Center for the study of Language and Information, 2006) and Sun-Joo Shin, *The Logical Status of Diagrams*, (Cambridge: Cambridge University Press, 1994). For a less analytical and more cultural prespective interested readers should see, Ola Soderstrom, "How Images Assemble the Urban World," in *New Geographies 4: Scales of the Earth* (Cambridge, MA: Harvard University Graduate School of Design, 2011)