25
MODELS AND MAPS

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1. Introduction

Generatively ambiguous, the concept of a *map* finds its natural home in cartography. The geographer John Andrews archived 321 definitions of the term published between 1649 and 1996. The single characterization dominating all others is "a representation… in a plane… of all or part of the earth's surface" (Andrews 1996, 1). This is a map as a representational cartographic object. In the first and wonderfully philosophical chapter of their book *The Nature of Maps*, the cartographers Arthur Robinson and Barbara Petchenik provide the following definition: "a map is a graphic representation of the milieu" (1976, 16). The *Oxford English Dictionary* catalogs further instances of this tradition of dramatic cartographic representationalism.

In contrast, and in line with dialectic tensions and perennial discussions in the philosophy of science, some cartographers and geographers beg for a more practice-based conceptualization. Geographers Rob Kitchin and Martin Dodge argue, "that cartography is profitably conceived as a processual, rather than representational, science" (2007, 331). J.B. Harley worried about the relation between "cartographic rules" and "the cultural production of the map": "In the map itself, social structures are often disguised beneath an abstract, instrumental space, or incarcerated in the coordinates of computer mapping" (1989, 4–5). Finally, Denis Wood portrays maps as "weapons" wielded by those with power – the state, the military, or the corporate elite (1992; 2012).

The contrast between representation and theory on the one hand and process and practice on the other is familiar to cartographers as well as to philosophers of science, showing one way that maps and mapping raise questions about models and modeling in general. In this chapter, I archive map discourse in the founding generation of philosophers of science (Section 2) and the subsequent generation (Section 3). In focusing on these two original framing generations of philosophy of science, I intend to remove us from the heat of contemporary discussions to see, in a more distant and neutral light, the many productive ways in which maps can stand in analytically for scientific theories and models. I also expand on what I take to be the map analogy – i.e., *a scientific theory is a map of the world* (Section 4) – illustrating its fruitfulness for understanding abstraction, representation, and practice in science.

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2. Archive I: the founding generation of philosophy of science and map discourse

Maps and mapping provide ubiquitous inspiration and intuition pumps, as it were, for the philosophy of science literature on representation and models. To name just a few examples, I will consider how maps are deployed as analogies for scientific representations by four figures from the founding generation of professionalized philosophy of science: Rudolf Carnap (b. 1891, PhD. 1921), Nelson Goodman (b. 1906, PhD. 1941), Stephen Toulmin (b. 1922, PhD. 1948), and Thomas Kuhn (b. 1922, PhD. 1949). Of particular interest here is the extensive use of the map analogy made both by the structuralist Carnap and the pragmatist Goodman.[1]

Turn first to Rudolf Carnap's 1928 *Aufbau* (1967/2003). According to Michael Friedman, the "fundamental aim" of the *Aufbau* was "the articulation and defense of a radically new conception of objectivity" (1987, 526). For Carnap, objectivity was intimately linked to "logical form or structure" (526). This form amounted to a system of "structural definite descriptions," a rich and enormous network of scientific concepts, within which each unique scientific concept finds its place. This central aim is developed in §§12–15 of the *Aufbau*, including the single-longest "concrete example" in the book, a map of "the Eurasian railroad network." This example explores how we can identify and distinguish each node of the total global structure – i.e., each station or each scientific concept – by examining the number of edges of each node, and of the nodes connected to it. As in identifying each station node by topology and connectivity within a railroad structure, an important step toward scientific objectivity is finding the location of different concepts within the unified, deductive logical structure of a "constructional system" (Konstitutionssysteme).[2]

In his 1963 commentary on Carnap's *Aufbau*, pragmatically oriented philosopher Nelson Goodman deployed the map analogy to show how the philosopher is a map-making meta-scientist. Experience is the "territory" of the constructionalist philosopher's map-making enterprise: "the function of a constructional system is not to recreate experience but rather to map it" (552). Philosophers can even construct "alternative schemes" using cues from *Aufbau* (553).[3]

With the map analogy in hand, Goodman defends Carnap against two critics: the "anti-intellectualist" (e.g., Henri Bergson, whom Goodman mentions by name) and the "verbal analyst" or "ordinary language" philosopher (552–554). Contrary to the anti-intellectualist who decries a constructional system or map because it does "not recreate experience," Goodman argues that "the relevant question about a system or a map" is not a choice "between misrepresentation and a meticulous reproduction," but "whether [a map] is serviceable and accurate in the way intended" (553). Goodman implores: "let no one accuse the cartographer of merciless reductionism if his map fails to turn green in the spring" (553). The map is not the territory. Anti-intellectualists, Goodman believes, are disingenuously indicting Carnap for conflating map and world, something Carnap was not doing.

Concerning the verbal analyst, Goodman admits that "verbal analysis is a necessary preliminary and accompaniment of systematic construction" but finds it counterproductive for the verbal analyst to be hostile to the constructionalist mapper (554). Although they are presented in an "artificial language" (like constructional systems), maps have "advantages." They are "consistent, comprehensive, and connected," "reveal unsuspected routes," "rectify misconceptions," and give "an organized overall view that no set of verbal directions and no experience in travelling can provide unaided" (553). The verbal analyst, Goodman argues, need not perceive Carnap and other constructionalist mappers (including Goodman) as competitors or foes. A constructional definition is not privative. Rather than implying that there "is nothing more than" the map and its elements, the map has a critical self-awareness built in so that it should be read as making the careful claim only of "is here to be mapped as" (554).[4] In a loose sense, reality has a one-to-many relationship with all of the legitimate maps that may be made of it. In short, Goodman interprets the constructionalist as wishing neither to conflate nor to confuse map and territory, nor as claiming to have an absolute, total representation.

Carnap approved. In the 1961 preface to the second edition of the *Aufbau*, Carnap admiringly noted that Goodman's constructional system had "essentially the same goal as my own" (1967, x). In his 154-page response to his critics in *The Library of Living Philosophers* volume dedicated to him, he also commends Goodman's "comparison … of construction with the drawing of a map" since it "clears up misunderstandings which are the basis of many criticisms of constructionism." According to Carnap, Goodman "emphasizes correctly" that "a total language is not intended to copy or picture reality either as a whole, or in part, or on a diminished scale, but to represent the relations among the objects in question by an abstract schema" (1963, 940). Carnap's structuralism and constructionalism, which he believed reflected a new "style of thinking and doing… which demands clarity everywhere" distinguished (linguistic) abstractions from reality (1967, xviii; this preface to the first edition is from 1928.).

A third example from this generation is Stephen Toulmin's analysis of "the analogy between physical theories and maps" as found in chapter 4 of his *Philosophy of Science: An Introduction* (1953/1960, 105–139). Toulmin's pioneering discussion is worth considering in detail.

First, Toulmin considered the scientist – especially the physicist – a "surveyor of phenomena" (110). Cartography involved empirically grounded inferential uniformity: "from a limited number of highly precise and well-chosen measurements and observations, one can produce a map from which can be read off an unlimited number of geographical facts of almost as great a precision." Such uniformity also obtained, Toulmin thought, in science: "a limited number of highly accurate observations on [physical] systems" allowed one to formulate a theory, which then underwrote "an unlimited number of inferences of comparable accuracy" (111).

Second, according to Toulmin, an important scientific project was to derive more context-bound, "refined" theories from "fundamental" theories. He drew explicitly on maps: "the relation between geometrical optics [i.e., the refined theory] and the wave-theory [i.e., the fundamental theory] is not unlike that between a road map and a detailed physical map" (115). The latter sort of map Toulmin characterized as "the fundamental map on which the Ordnance Survey might record all the things which it is their ambition to record." That is, geometrical optics and road maps are derived, respectively, from wave theory and a fundamental map through "selection and simplification" (116). Abstraction permits the production of evermore contextual and purpose-specific scientific theories – or, I would add, models – and maps.

Finally, maps negotiate and synthesize the truth and correctness of representations with their use and implementation. In these efforts, both precision and conventions are essential:

> Cartographers and surveyors have to choose a base-line, orientation, scale, method of projection and system of signs, before they can even begin to map an area. They make these choices in a variety of ways, and so produce maps of different types. But the fact

> that they make a choice of some kind does not imply in any way that they falsify their results. For the alternative to a map of which the method of projection, scale and so on were chosen in this way, is not a truer map—a map undistorted by abstraction: the only alternative is no map at all.
>
> *(127)*[5]

Maps (and theory) must distort (and be distorted), and choices about how and what to represent must be made. It is only through such choices that something – i.e., a representation – exists to which "facts" "can be true to *or* falsify" (127).

In short, and without claiming to exhaust Toulmin's many uses of the map analogy, Toulmin draws on basic cartography to usefully describe theory construction as involving the surveying of phenomena; to capture the relation between fundamental and refined theory; and to negotiate truth and use of representation.

This section has attempted to archive at least some of the key uses of the map analogy by first-generation professional philosophers of science. Already, perennial themes of the philosophy of science can be seen to emerge: the use of cartographic objects to illustrate logical structure and conceptual topology; the importance of distinguishing representation (map; theory, model) from world (territory; object, target); and the necessity of negotiating the content and abstraction with the development and application of scientific representations. We see this last point, especially in the single place in *The Structure of Scientific Revolutions* where Thomas Kuhn used the map analogy, observing: "paradigms provide scientists not only with a map but also with some of the directions essential for map-making. In learning a paradigm, the scientist acquires theory, methods, and standards together, usually in an inextricable mixture" (1970, 109).[6]

3. Archive II: the second philosophy of science generation sharpens the map analogy

The second generation of philosophers of science consistently relies on the map analogy to accentuate the purpose- and scale-relative nature of scientific representation, as well as highlight the importance of the partiality and creativity of scientific models.[7] Their efforts increasingly turned to the actual work theories and models do in the world (the so-called "practice turn"), as opposed to the first generation's concerns with rationally reconstructing the structure of physical and biological theories.

For this archivist project, the focus will be on three figures, first sketching Philip Kitcher's uses of the map analogy to elaborate a kind of pragmatic realism and then using my concept of *contextual objectivity* as a conceptual umbrella to explore Helen Longino's and Bas van Fraassen's analyses of the map analogy.

In his 2001 book, Philip Kitcher devotes an entire chapter, titled "Mapping Reality," to philosophical cartography. Very much in line with the third feature of the Toulmin discussion above, Kitcher cares about interpenetrating accuracy and application of representations, whether cartographic or scientific. There is no trade-off between accuracy and convention, nor are they mutually exclusive. There is a single complex world, Kitcher insists, noting that realism is "perfectly compatible with recognizing the fact that human interests change and, in consequence, maps are drawn with very different reading conventions" (2001, 58). In map-making, we divide "the world into things and kinds of things," "depending on our capacities and interests" (59). Analogously, in scientific knowledge production, we classify the parts and properties of the world in various ways and identify and favor different sorts of regularities, causes, and laws (of the world) according to questions of concern (72). The world can be cut in various convention-dependent manners.

Kitcher draws a surprising lesson from the map analogy. He goes so far as to argue that, given the conventions, "the map of the [London] Underground is not *approximately* accurate. It is exact" (59). This is because once we have specified what he calls the *intended content* – i.e., "the region and the types of entities and properties that the map intends to portray" – as well as the *reading conventions* – i.e., the conventions that "link items in the visual display to those [physical] entities and also specify which features of the display do not correspond to any aspect of nature [e.g., the Underground tunnels are not literally colored as in the map]" – then the map is exactly accurate (57). Does the same hold for scientific representation? We are not exactly told, but it would seem so. The important lesson is that accuracy and convention require one another and are both necessary for appropriate and useful cartographic and scientific representation.[8]

In *When Maps Become the World*, I drew on two members of the second generation of philosophy of science to develop my concept of *contextual objectivity*, or "the quality resulting from good and proper application of a representation" (2020a, 95). Accurate bike maps of Copenhagen, Amsterdam, or San Francisco are contextually objective for biking purposes. However, such maps are neither precise, informative, nor useful – i.e., not in any way objective – for a geologist who wishes to know about the kinds of soils, minerals, and fossils that might be found in these cities. Ditto in science, where accurate theories and models are also highly contextually objective when used for the particular ends for which they were designed. As biologists Richard Levins and Richard Lewontin (1985) write, "the problem for science is to understand the proper domain of explanation of each abstraction rather than become its prisoner" (149–150).

Could a bike map like those mentioned above be considered true, approximately true, or even true only for certain local purposes, without being true in general? This might appear like an odd question. But different aspects and elements of the map fit, are accurate, and capture the world in distinct ways. *Truth* seems too generic a success term to capture such varieties of fit. One option for addressing myriad concerns about fit and accuracy, whether in map-, model-, or theory-making (e.g., confirmation) or map-, model-, and theory-use (e.g., explanation and understanding), is a more pluralist strategy about modes of epistemic success. That is: permit a plethora of success terms, depending on the epistemic and pragmatic aims and values of the scientist, scientific community, or public at large.

In *The Fate of Knowledge*, Helen Longino draws on map discourse to develop a contextualist proposal of reference pertinent to scientific theories and models: the *conformation* account. Conformation is a capacious concept delineating a family of epistemic success terms (2002, 117). There is no single, monist principle of justification or truth:

> Maps fit or conform to their objects to a certain degree and in certain respects. I am proposing to treat conformation as a general term for a family of epistemological success concepts including truth, but also isomorphism, homomorphism, similarity, fit, alignment, and such notions. Classical truth is a limiting concept in a category of evaluation that in general admits of degree and requires the specification of respects.
> *(117)*

Different cartographic criteria of fit can be deployed. For instance, is the exact location of relevant features or objects necessary, or is their relative topology sufficient? Finished maps generated by the second criterion (e.g., the famous – not to say clichéd – London Tube map) will be justified differently (and look different) than those generated by the first (e.g., a London street map).[9] If empirically verified by its own criteria, each map can be relevantly precise and accurate – i.e., conformational – for different users and uses, as it is with scientific models. Extracting further from the analogy between map conformation and model (and idealization)[10] conformation, Longino continues: "like maps, models must be sorted out into grades of adequacy in multiple categories, rather than into a single binary category" (118). Thus, Longino deploys the map analogy to argue that a variety of representation relations and criteria of representational accuracy are at play in cartography and science in general. The pragmatic context is critically important in choosing among these and concretizing any one of them in particular.

This contextualism holds not only for the representational relations of mapping and modeling but also for evidence as such. "The pluralist philosopher," Longino says, holds that "it makes no sense to detach measurements and data descriptions from the contexts in which they are generated, or that, as soon as one does, one creates a new context relative to which they are to be assessed and understood" (201). No neutral observation language is necessary or possible for confirmation. After all, different approaches may use commensurable data to produce distinct representations and knowledge of the same system, "each of which conforms to that system differently as both Mercator and Peters projections produce two-dimensional maps that conform, but differently, to the topography of the spherical planet Earth" (201).

Conformation is a broad concept of "epistemological success" marking the appropriate use of an abstraction or representation. I interpret conformation as a component of contextual objectivity: Longino's concept helps us understand the context-dependency and epistemic specificity of partially objective representations and their components.

The map analogy demands an explicit acknowledgment of the simultaneous role of the objective and the subjective. Diverse subjects with locally situated purposes and politics produce public cartographic abstractions representing the (objective) world. This is also the case with scientific theory, as seen in the book *Scientific Representation: Paradoxes of Perspective*. On the one hand, Bas van Fraassen holds that scientific theories, with their model structures, can "be written in coordinate free, context-independent form" (2008, 82). That is, scientific theories are detached, public, and express a "view from nowhere" – they are objective.[11] On the other hand, in order to test or apply information contained in scientific theories, the scientific community must situate the user in the context of the theory (82).[12] Our theories are *also* personal, biased, and express a "view from the inside," as it were.

Van Fraassen insists on the simultaneous importance of subjectivity and objectivity in cartographic endeavors, and, by extension, in science. The map analogy strongly motivates his attempts to show that scientific theories and models are context-independent as well as user-specific – objectivity and subjectivity reach a synthesis. He draws from Immanuel Kant, who discusses the necessity of having both "a map of the heavens" and knowing how "my hands" are positioned relative to it if one wishes to infer where on the horizon the rising sun will appear (1768/1992). In a section called "Mapping and Perspectival Self-Location," Van Fraassen develops the "inevitable indexicality of application" (2008, 80) in light of Kant's map example. Through the concept of the *essential indexical*, van Fraassen argues that maps and scientific theories are context-independent in their universality, detachment, and public availability (i.e., their objectivity) as well as user-specific and therefore biased in their application (i.e., their subjectivity). But what is this essential indexical (2008, 3, 83, 88)?[13]

In order to use a map, we must know where we are *on* it. In this moment of application, we take the map's context-independent information and make a context-bound location judgment, and perhaps even an itinerary that allows us to get from Point A to Point B. And since "models" and "maps" are equivalent "metaphors," according to van Fraassen, it is also the case that "we must locate ourselves with respect to that model" (83). That is, the act of application requires subjective indexicality in scientific modeling as much as in mapping. Precisely because science is "use[d]," we have to let in "consciousness and agency." And to those who would seek to banish subjectivity from science, van Fraassen says, "We will just have to admit a non-pejorative sense of 'subjective', if the essential indexical has to be labeled as something subjective" (83).

In his 1992 presidential address to the Philosophy of Science Association, van Fraassen counters critiques of his anti-foundationalist theory and epistemology of science.[14] The map analogy drives the argument in the first three sections. Van Fraassen concludes that those who dream of a non-theoretical observation language are wrong to relinquish a contextual role for experience in models, maps, and language: "[in] maps and language equally [,] we need, and aim to have, accuracy only in *relevant* respects - inaccuracy elsewhere does not pre-empt the criteria of correctness of self-location with respect to them" (1992, 14). We also learn that "the topic of self-ascription belongs to pragmatics and not to semantics" (7). Pragmatics is necessary to understand the application of science in designing and building technology.

In short, subjectivity and objectivity, accuracy and inaccuracy, pragmatics and semantics, are all required for a full understanding of experience in science. It would be a grave mistake, van Fraassen (1992; 2008) argues – and I concur – to throw the fallible and contextual observation baby of actual science out with the theory-neutral and unified experience bathwater of the positivists. Van Fraassen's (and Perry's) essential indexical is an analytical component of contextual objectivity. The essential indexical highlights the centrality of the user of representations, and also the creator of new representations based on old ones.[15]

There is a strong pragmatic streak in Kitcher's realism, Longino's concept of conformation, and van Fraassen's concept of the essential indexical. They draw on map discourse – and on the map analogy – to illuminate the non-binary nature of scientific theorizing and modeling: accuracy and convention, objectivity and subjectivity, and context-independence and context-dependence are dialectical poles of different spectra that are simultaneously important.[16] Moreover, a plurality of representational and epistemic success relations is necessary for a full comprehension of how scientific representation works.

4. Expanding the map analogy

A pattern of reasoning emerges: as in cartography, so in the philosophy of science. One might say that cartography is the source domain, while philosophy of science is the target domain. When thinking or reasoning analogically, one item or feature from one type of domain, field, or case is compared to – and, hopefully, found in – another domain, field, or case. When the same object or characteristic is found across domains, we say we have or have found a *positive* analogy; when the analogy fails and we do not have the item or feature of the source domain in the target domain, the analogy is *negative* – some might say we have a *disanalogy*; and when we do not know, the analogy is *neutral*.[17] Isaac Newton found positive analogies between fast projectiles and planets in orbit, and Alfred Wegener analogized icebergs on water to continents floating on Earth's hot, inner geological fluid (Newton 1728; Wegener 1966). Here is the central, basic map analogy (Winther 2020a, 29; compare Sismondo 1998; 2004):[18]

A scientific theory is a map of the world.

Both theories and maps are simplifications and idealizations imposing counterfactual assumptions. Both portray only a small subset of the properties and processes of their respective targets – world and territory – in purpose-dependent manners. And both, I have argued, can all too easily be confused and conflated with their target – a phenomenon I call *pernicious reification* (Winther 2014; 2020a; 2020b; compare Dupré and Leonelli 2022.). Indeed, "If pernicious reification is an epistemic and practical failure, contextual objectivity is a knowledge-enhancing and concrete success" (2020a, 90). As is always the case with analogical reasoning, the map analogy breaks down in places. But it is fruitful and beautifully pervasive, as we have also seen above.

In many respects, there is continuity and similarity between the concepts of theory and model. The first two generations of philosophers of science primarily spoke in terms of theories, viewing models either as specific physical instantiations or "analogies" to theories (e.g., Mary Hesse) or as formal offshoots or pieces, as it were, of theory. Nancy Cartwright forced a "modeling turn" in the philosophy of science in the 1980s when the philosophy of science increasingly focused on models. We are still coming to terms with this shift (Cartwright, 1983).

In 2010–2011, I sent a survey to 20 eminent scientists and received 16 responses. This survey included the question "What do you think is the difference between theory and model, if there is any?" The respondents distinguished these two in varied ways. Common distinctions included that theories were quite general and broad and covered many potential and actual phenomena, while models were more local and built-to-purpose. Regardless, it was obvious that both were deemed important, and they were taken to interact. (Of course, today, a decade later, answers might differ.)

In consideration of the above, the potential utility of a distinct analogy for models became evident. A few are on offer already. Cartwright, Shomar, and Suárez proposed the *toolbox* view of science, in which theory was but one input to making a model:

> real things… are represented by models, models constructed with the aid of all the knowledge and technique and tricks and devices we have. Theory plays its own small important role here. But it is a tool like any other; and you can not build a house with a hammer alone.
>
> *(1995, 140)*

In contrast, Marcel Boumans tells us that "model building is like baking a cake without a recipe. The ingredients are theoretical ideas, policy views, mathematisations of the cycle, metaphors and empirical facts" (1999, 67). Both the toolbox and the baking analogies have strengths. So does, I think, a model map analogy, which replaces "theories" with "models" in the analogy above. Each has strengths and illuminates different features of models.

Therefore, I would like to add the following model analogy to the mix:

A scientific model is a vehicle for understanding.

Let us take seriously the play on the term "vehicle," precisely because it does seem to capture important analogies between the physical and the phenomenological, as well as between the objective and subjective. After all, as already Lakoff and Johnson (1980) taught, language captures important correspondences between bodily features and cognitive or moral properties. In its simplest meaning, a vehicle is a train, bike, boat, and, of course, a car. It helps you get from Point A to Point B. Because of work, family, pleasure, or curiosity, we often need – or just wish – to get to a new physical place and space. A vehicle, then, is necessary for satisfying our needs and desires to move our bodies (and minds) to new places.

This sense of movement, I believe, also helps capture what a scientific model can do. It can help us "move" from a state of ignorance or incomprehension to a state of understanding. Since models are somewhat concrete, local, and idealized scientific constructs, we can play with them and draw out lessons about climate, alleles in gene pools of populations, and gravitational waves. In their specificity, models transport us from confusion to understanding. Theories can also do this, but the modeling turn has taught that models are much more concrete playthings helping us along in understanding and intervening in the world.

Consider for a moment an electric vehicle, both literally and metaphorically. Literally, an electric car has new technologies questioning our assumptions about fossil fuel consumption (but of course worries regarding the extractivist mining of rare earth metals abound, and perhaps *reducing* consumption – and *degrowing* our economies – in general would be better). Metaphorically, an electric car qua vehicle is a collection of collective and norm-driven processes interacting with physical technology, that permits us to travel efficiently and (arguably) sustainably from Point A to Point B. We travel or are moved from incomprehension or ignorance to understanding. This version of a vehicle thus analogically captures the locality, complexity, and epistemic value of models.

But a vehicle qua transportation is not the only vehicle possible. I suggest that just as we can broaden the cartographic object from a standard topographical map to a political or military map to, for instance, a geological or extreme-scale or state-space map (Winther 2020a; 2024), so can we expand the notion of vehicle metaphorically, to be the *apparatus* needed to satisfy our aims of interacting with the world. Thus, the vehicle for a scuba diver includes diving gear and air tanks. The vehicle for a hiker includes all the hiking gear. The vehicle for a scientist, all the instruments, lab spaces, computers, etc. This is a version of the *epistemic artifacts* view of models by Tarja Knuuttila and Natalia Carrillo (Knuuttila 2011; Carrillo and Knuuttila 2021). *Models move us towards scientific understanding and they are the scaffolding we require for understanding*.[19]

And, importantly, models do so in constant feedback with general theories. At the risk of being repetitive: if a scientific theory is a map of the world, then a scientific model is a vehicle for understanding. And the analogies are dialectical – we need abstract/general maps and concrete/artifactual vehicles, in interaction, both cognitively and socially, to achieve understanding. The map "points," and the vehicle "moves." The theory-map analogy and the model-vehicle analogy illuminate the interrelation and back-and-forth of models and theory. Models are not "models of theory," but they require theories and theoretical components as one aspect of their structure, development, and use.

5. Conclusion

To be fair, not all philosophers of science have embraced map discourse and the map analogy. Karl Popper was skeptical: "the familiar analogy between maps and scientific theories [is] a particularly unfortunate one." For him, maps were only descriptive and "non-argumentative"; in contrast, theories were "argumentative systems of statements" that could explain and describe deductively (1982, 86). Admittedly, Popper's deductive, normative falsificationism does not on the surface articulate well with a pragmatic reading of the map analogy, but I suspect it might upon further exploration (e.g., maps have a normative ontology).[20]

The analogy – or set of analogies – between maps, mapping, and cartography on the one hand and scientific theories and models, theorizing and modeling, and science on the other has been extensively explored by philosophers of science. In this chapter, I have reviewed some uses of the map analogy in the founding generation of philosophers of science as well as the second generation. Especially the latter interpreted the map analogy in pragmatic ways, while the former was perhaps more exploratory. Thinking cartographically allows us to think in non-dualistic and dialectical manners about structure and practice, representation and world, and truth and convention in the philosophy of science.

Notes

1 Other philosophers of science in the founding generation include Paul Feyerabend (b. 1924, PhD. 1951), C.G. Hempel (b. 1905, PhD. 1934), Mary Hesse (b. 1924, PhD. 1948), Ernst Nagel (b. 1901, PhD. 1931), Karl Popper (b. 1902, PhD. 1928), Patrick Suppes (b. 1922, PhD. 1950), and J.M. Ziman (b. 1925, PhD. 1952). My discussion here significantly expands my earlier too-brief discussion on Carnap and Goodman (Winther 2020a, 46–47).

2 For a discussion of Carnap's project and its rich cultural context, see Daston and Galison (2007, chapter 5 "Structural Objectivity," esp. pages 289–296 and Fig. 5.7 "Structural Map," page 292). See also Leitgeb and Carus (2022), whose "Main Point and Motivation of the *Aufbau*" section summarizes a telling 1929 popular lecture Carnap gave. This lecture contrasted "critical intellect" and "imagination," claiming that human culture started with the latter, but developed the former through "the discovery of *one* [single] *comprehensive space*." Furthermore, critical intellect eventually abstracted this physical space into "an all-comprehending conceptual space" (Carnap's own terms, as presented by Leitgeb and Carus 2022).

3 On Goodman's own constructionalism, see Goodman (1951).

4 In an analogous manner, William James critiques "vicious abstractionism," which interprets concepts as involving "nothing but" definitions. See James (1909); Winther (2014; 2020a; 2020b).

5 In my 2020 book, I present a compressed version of this quote (footnote 24, 96), and a too-brief discussion of Toulmin's deployment of the map analogy (ibid and footnote 1, 60).

6 As explored in Winther (2020a, 195–196), Kuhn also used the map analogy in an essay, "Possible Worlds in History of Science" (2000b), addressing matters of translating and interpreting lexica or vocabularies (alternatively: ontologies or taxonomies) of historical paradigms into later scientific languages. This essay resonated with an earlier essay's themes about incommensurability, translation manuals, and "taxonomic categories of the world" (Kuhn 2000a, 52).

7 This generation includes Nancy Cartwright (b. 1944, PhD. 1971), John Dupré (b. 1952, PhD. 1981), Michael Friedman (b. 1947, PhD. 1973), Ronald Giere (b. 1938, PhD. 1968), Helen Longino (b. 1944, PhD. 1973), Thomas Ryckman (b. 1950, PhD. 1986), and Bas van Fraassen (b. 1941, PhD. 1966), most of whom received their PhDs in the 1970s. Aptly, Ian Hacking (b. 1936, PhD. 1962) falls between this generation and the first.

8 These particular Kitcherian lessons of the map analogy are not discussed in Winther (2020a). Others are.

9 Ziman distinguishes four maps of London: a highway map, "a street directory," a bus route map, and the underground map. He observes: "these four maps all cover the same region on much the same scale, and in spite of various simplifications are all essentially 'truthful'" (2000, 129).

10 Longino notes that idealizations also have various criteria of appropriateness: "Like maps, they are useful just because they do not represent any particular situation, but rather make salient a feature common to a family of similar situations, and in particular because they make salient a feature in which the law's users are interested" (2002, 117).

11 Elisabeth Lloyd critically reviews "four distinct meanings of 'objective' and 'objectivity' that are currently in broad use in contemporary philosophy" (1995, 353), as well as different forms of contrast between objectivity and subjectivity. Nagel (1986) stands as one defense of objectivity as a "view from nowhere."
12 Toulmin drew on the map analogy to motivate non-exclusive distinctions between science and technology, and representing and intervening (compare Hacking 1983).
13 Perry (1979) influentially developed this concept in a philosophy of language context.
14 Interestingly, this 1992 address contains language identical to van Fraassen (2008) on the "self-ascription of location" in maps and in models and is a piece worth examining on its own terms (see, e.g., van Fraassen 1992, 7).
15 Winther (2020b) urges caution with exaggerating a centralized, "world navel" point of view.
16 See Winther (2021a) for the analysis of dialectics used in this chapter.
17 Hesse (1966; 1967) developed this language; compare Bartha (2010).
18 See Winther (2021b) for a general analysis of scientific theory, and of shifting understandings of theory in the philosophy of science.
19 On the philosophy of science of understanding, see de Regt, Leonelli, and Eigner (2009) and Grimm, Baumberger, and Ammon (2017). In instructive conversations, James Griesemer reminds me of the importance of compasses and "navigationism" as supplements to maps and "representationalism."
20 For a "multiple representations account" of the "ontological layer" of maps and models, see Chapter 5 of Winther (2020a). For a philosophical analysis reversing the map analogy – i.e., maps-as-models rather than models-as-maps – see Frigg and Nguyen (2020) and Nguyen and Frigg (2023).

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