CARTOGRAPHY IN THE CONTEXT OF SCIENCES: THEORETICAL AND TECHNOLOGICAL CONSIDERATIONS

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Abstract

In an introductory theoretical way the authors attempt to place cartography into the general context of sciences. Based on the traditional definition describing cartography as a science, technique and art, its defined scientific role in the development of geographic thinking is analyzed. This approach corresponds to the procedural method in epistemology. Cartography is, according to a general model in science, classified considering the fact whether its sources of origin of the concepts, its principles and postulates are genuine or derivatives from other disciplines. After comparative statements between Cartography and Geography an analysis of all *environmental sciences* with reference to the technologies use is carried out.

Keywords: Theoretical Cartography, Geographical Conception, Epistemology, Basic Sciences, Applied Sciences

Introduction

This article has the general intention to analyze cartography in its theoretical dimension, and at the same time tries to put the discipline into the general context of sciences. It is important to emphasize that this theoretical analysis is framed in the neopositivistic perspective of scientific knowledge.

In 1949 cartography was officially acknowledged as an independent science (UN Documents, I, 19, p. 8). If cartography is considered as a science, it is relevant to identify what type of science (*basic sciences; applied sciences; natural sciences; social sciences*) it belongs to and what its characteristics are, as well as its principles, concepts and postulates, and to examine whether these are genuine or derived from other sciences or disciplines.

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There exist several definitions for cartography. There are traditional ("classical") definitions which describe it as a science, art and technique for map making. Technique implies the way how to generate accurate and precise cartographic products in an analogue or digital format. The aspect of art basically refers to the cultural and historical context where maps express more than only the objective elements of the landscape (Cartwright et al. 2008). On the other hand, at the beginning of the second half of the twentieth century when cartographers began to focus their research on cartography *per se* the scientific definition of cartography was driven by its disciplinary context, as first formulated in the milestone-book *The Look of Maps* by Arthur Robinson published in 1952 (cf. Montello, 2002).

Regarding the theoretical aspect of cartography Koch (2002, cum lit.) refers to the progress and the scientific development of the discipline since the 1970s, mentioning *Theoretical Cartography* or *Theory of Cartography*. Under these topics of course fall "cartographic theories" developed by authors such as Aslanikashvili, Ratajski, Freitag and Ogrissek.

For these reasons, cartography is considered as a relatively young scientific discipline in comparison to physical sciences, which have developed during the 17th and 18th century, or social sciences, which have developed in the 19th century (Sluter, 2001). For an epistemological study of the discipline it seems therefore justified to consider the evolution of the major *mother science* of cartography, geography. Geography has been the discipline closest to map-making, from its early beginnings through the Greek and Latin periods, the Middle Ages, Renaissance, and Modern Times up to now (Varcárcel, 2000). Therefore, geographical conception which, in comparison to the scientific approach in cartography, has a long tradition may first and foremost provide the epistemological coordinates that contextualize and act as a reference for any attempt to treat cartography from a scientific and disciplinary perspective.

Concerning the relations between cartography and other sciences Ogrissek (1987) considers both geography and geodesy as *mother disciplines* of cartography and states that these relations are *genetic* which justifies calling them *mother sciences of cartography*.

In theoretical cartography models have been developed to show the links between cartography and other disciplines. For example, Ogrissek (1987) indicates in his *structural model of theoretical cartography* the existing relation between the *general theory of map organization* and the *general theory of map use*. This model shows a series of links originating between various other sciences and disciplines and topics or subjects of cartography belonging to both aforementioned theories.
On the other hand, concerning the position of *Theoretical Cartography* in the basic scheme of cartography, Koch (1995) locates it under the *umbrella* of *cartography as a*

science, besides *Empirical Cartography* and *Cartographic Methods* and puts it into contrast to *Applied Cartography*. In this scheme the author also treat relations between *Theoretical Cartography* with other components.

Based on the above statements and before approaching cartography *per se*, in the following an analysis of the geographic science will be made using a methodological scheme of comparisons between different disciplines referring to the origins of their principles and the fact if these are genuine or derivative. According to postulates, principles and theories different disciplines are classified, distinguishing those that develop of its own volition, the ones which make use of elements deriving from other disciplines, and those *borrowing* their theoretical basics (principles, rules, laws) from other disciplines.

GEOGRAPHY AND ITS SCIENTIFIC STATUS

With respect to the branches of science, in a first instance Bunge (1998) distinguishes between *formal sciences* and *factual sciences*. This implies that the first ones are dealing with ideas, and the latter ones are dealing with facts. *Factual sciences* are divided into *natural sciences* and *cultural science*. In Table 1, all types except for the first one (formal sciences) correspond to factual sciences. In comparison to formal sciences, *Basic sciences* such as physics, chemistry and biology are considered second type. The physical/natural sciences and the social/human sciences are considered as third type because both derived from the basic sciences. And other sciences are comprehended in the fourth type, because they derived from the previous ones.

Richard Chorley and Peter Haggett (1967) and David Harvey (1969) proposed a theoretical-scientific framework for geography in the context of the *neopositivistic paradigm* which came up in the second half of the 20th century. This can be considered the hour of birth of theoretical geography which claims that theory in general is the articulator and the orientation axis for research of and explanation for the geographical phenomena. The idea of Harvey was to establish geography's position within the overall framework of sciences.

Science Type	Science Classification	Sciences, disciplines
1st type	Formal sciences	Logic; Mathematical
2nd type	Basic sciences	Physics; Chemistry; Biology
3rd type	Physical/Natural sciences	Geology; Climatology; Geomorphology; Glaciology; etc.
	Social/Human sciences	Sociology; History; Economy; Politics; Anthropology; etc.
4th type	Geographic sciences	Physical Geography; Human Geography; Regional Geography

Table 1. Geography in the context of sciences

According to this framework (see Table 1), physical geography is placed within the geographic sciences. Therefore, it belongs to the category of the fourth type, since its studies mainly make use of the physical/natural sciences - the third type, which as well have their foundation in the second type category, the basic sciences (physical and chemical). Considering this framework, formal sciences belong to the first type (logic and mathematics).

In 1967, Berry (cited by Harvey, 1969) stated for example that meteorological and climatic analyses, falling into the category of physical geography, refer to six basic laws, the two first ones of which are the First and Second Law of Thermodynamics, and the remaining ones are specific meteorological laws based on Newton's Laws of Movement, i.e. laws belongs to physics.

On the other hand, the studies in human geography, like in physical geography, derive from sciences of the third type (social/human sciences) and, according to certain paradigmatic approaches, especially the ones originating from the positivism of the nineteenth-century, are supported by laws of nature deriving from biology. Therefore, the human studies in geography are making indirect use of sciences of the second type. For instance, the analysis of urban zonings in human geography is determined by land-use models. Studies like this come from the *Chicago School of Ecology* which claims that cities behave like living organisms, and consequently some regular and evolutionary patterns can be identified through time, based on the laws which determine the human behaviour (Gómez Mendoza, et al., 1988).

Another aspect corresponds to regional geography which, in spite of considering elements of sciences of the third type (interrelation of natural, social and economic elements which occur at concrete locations), is mostly not interested using genuine principles and postulates of basic sciences. Its objectives of research are rather aiming at the characterization of the individuality or *uniqueness* of places and territories.

Nevertheless, according to some learned geographers like Chorley and Haggett, 1967 – as a sort of forerunners - *quantitative geography* is supposed to deserve a *higher scientific status* than merely *descriptive geography*. This new geography, which was born out of the neopositivistic paradigm, is a science that derived from the first type of sciences (cf. Table 1) due to its links with geometry and topology, which are both branches of mathematics. Quantitative geography uses postulates originating from formal science. For instance, considering certain assumptions, the geographic analysis of spatial distribution of assessments relies on geometric aerial units like the hexagon (Chorley and Haggett, 1967). Traditionally these geometric figures were considered as *models* to optimize the transportation costs, for example from the center to the periphery, or the peripheral length of a polygon.

Therefore, despite quantitative geography being a science of the third type, the models of abstraction coming from formal sciences like mathematic are used for its analysis and comprehension. Thus, one can argue that geography, referring to the neopositivistic view, represents a new, fourth science type of its own, i.e. *Geographic Sciences*, which contain components that derive from the first type listed in the aforementioned classification scheme of sciences.

The position of cartography within the framework of sciences

The same way Harvey (1969) established the position of geography within the framework of sciences, cartography shall be compared with other disciplines and positioned in the aforementioned classification scheme of sciences. When determining the scientific dimension of a discipline, it is appropriate to carry out an analysis if it uses its own postulates and principles or if, like a great part of other disciplines, on the contrary it uses concepts and laws derived from other sciences.

In order to achieve this it has to be checked to what extent cartography belongs to *formal sciences* (first type), *basic sciences* (second type), *physical/natural sciences* and *social/human sciences* (third type; both derived from *basic sciences*) and *other sciences* (fourth type; derived from the previous ones). The results of an analysis of the contextual significance of cartography and its major branches in the aforementioned classification scheme are reported here.

In this context we subdivide the cartographic science into its two major internal branches (topographic and thematic cartography, both based upon the geometric framework of the respective map projections) which grant disciplinary identity. In the classification applied in this paper (see Table 2) cartography is positioned into the fourth category of science. This way, cartography is in the same position that geographic sciences, considering that different geographies constitute fundamental contributions and contents for their development, especially in spatial issues.

Science Type	Science Classification	Sciences, disciplines
1st type	Formal sciences	Logic; Mathematics
2nd type	Basic sciences	Physics; Chemistry; Biology
3rd type	Physical/Natural sciences	Geodesy; Astronomy, Geology; Climatology; Geomorphology; Glaciology; etc.
	Social sciences	Sociology; History; Economy; Politics; Anthropology; etc.
	Human sciences	Psychology; Semiotics; Hermeneutics; Phenomenology; etc.
4th type	Cartographic science	Topographic Cartography; Thematic Cartography

Table 2. Neopositivistic view of cartography in the context of sciences

The position of *Cartography* in the above classification scheme of sciences is based on the following aspects (Azócar, 2006a, b): *Topographic Cartography* makes use of some of the sciences of third type, the *natural sciences*, for the location and representation of its diverse variables, mainly the geomorphological and hydrological ones, by means of visualization methods that represent the relief. In contrast to *Thematic Cartography* elements represented in topographic maps are basically studied by *natural/engineering sciences* and to a lesser extent *social sciences* (infrastructural elements). The basic and direct support for *Topographic Cartography* comes from disciplines such as astronomy and satellite geodesy, both physical sciences.

Thematic Cartography has a strong relation to *geographic sciences*, especially human geography and regional geography. Also, in the stage of map design, it refers directly to *human sciences* using disciplines such as psychology and semiotics as well as using technical tools such as statistics and computer science. Nevertheless, the importance of *Thematic Cartography* is based on the depiction and communication of (additional)

"non-topographic", even abstract, facts and phenomena and their spatial characteristics. These thematic "variables" of the physical world belong to the *physical sciences* (except geodesy) and *social sciences* and their mutual interactions.

Cartographic projections, due to the analytical nature of their object of study, represent an aspect of cartography to which a greater scientific status may be assigned since it makes directly use of sciences of first type. Map projections are analytical instances based on principles and postulates that correspond to the mathematical ones, matrix algebra and spherical trigonometry. Therefore, a map projection is *per se* a formal entity of analytical character, thus corresponding to sciences of the first type. Its practical visual implemen-tation is represented by geometric grids (who belong to sciences of third type).

Treating the relations between cartography and other sciences Ogrissek (1987) refers to several authors who stated that a good part of geodesy has a close relation with *Topographic Cartography*, and that there exists also a strong relation between geography and *Thematic Cartography*. Those relations are remarkable, especially due to the intensified penetration of Thematic Cartography into probably all geosciences.

The classification scheme of Table 2 is misleading in that respect that the *formal sciences* which represent the major basis of disciplines are located "far away" from the *science of cartography*. In fact, they are similarly close as the *human sciences*. Figure 1 attempts to take this fact into account and displays the *formal sciences* as *the* nucleus of cartography which also builds upon the "*natural science*" of geodesy. Making use of *human sciences* like psychology, semiotics, phenomenology, etc. the *cartographic science* is applied to both *social sciences* and *geosciences* which are part of the *natural sciences*. *Basic sciences* like physics and chemistry only come into the game in the context of visualization/display techniques (analogue: printing; digital: electronic screens).

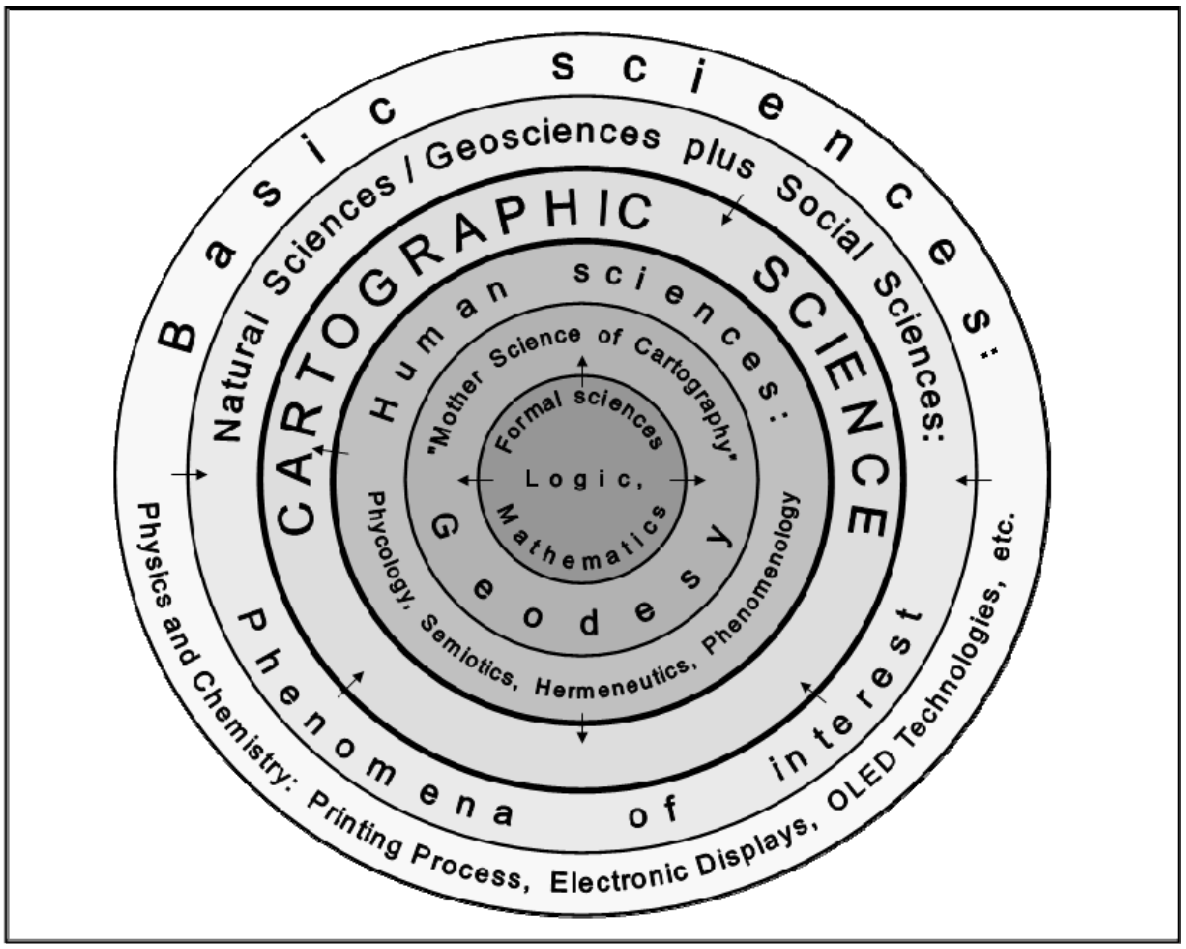

Figure 1. Cartography in the framework of sciences according to the neopositivistic scheme developed by Harvey (1969); based on an unpublished schematic diagramme developed by M.F. Buchroithner. Building on the "nucleus" of *formal sciences* and the supporting *human sciences* cartography serves to depict spatial phenomena of both the *natural* and the *social sciences.* The representation processes makes use of developments in the *basic sciences.* For further explanation see text.

In summary, cartography, in spite of being frequently considered a "*science of the fourth type*", directly uses principles and concepts of the *third type sciences*, i.e. the *physical/natural sciences* and postulates of the *first type sciences*, the *formal sciences* such as mathematics. On the other hand, geographic and cartographic disciplines reveal a noticeable difference regarding their theoretical development. When comparing *quantita-tive geography* with the field of *cartographic projections*, the first one makes only use of geometrical and topological principles in a referential or schematic way. However, for map projections the mathematical (geometric) principles are essential and solid constituents and go therefore far beyond a mere reference.

Methodologies and techniques

Looking at the technical developments of cartography we see that in the last decade of the 20th century a new typology of sciences arose, making use of terms like *environmental sciences* or *geomatic sciences*, which are accompanying the *earth sciences*. These new *termini* comprehend various disciplines of natural, social and applied sciences. Albeit, within the scientific community there exists (so far) no common agreement about the intrinsic components of these "*new sciences*". This is partly subject to the fact that there exist some disciplinary overlaps which permit the assignment of significantly more than one "*classical science*" to these new fields. The *environmental sciences* e.g. include geodesy/geoinformation technology, geophysics, geology, geography, climatology/meteor-ology as well as habitat research/ biology/botany, etc. Table 3 gives a summary of *science types*, their disciplines and the methodologies and techniques they use.

The *environmental sciences* have a close links with several applied sciences which in turn derive directly from *basic sciences*, for example from electronics and software engineering. Further, there exists a set of methodologies and techniques like remote sensing, geo-information systems, global positioning systems which are applied to accomplish different goals. These applications are commonly summarized as *applied geo-technologies* (cf. Table 3, lower right corner).

Science Type	Science Classification	Sciences, disciplines	Methodologies & Techniques
1st type	Formal sciences	Logic; Mathematical	Calculation; Computation; Modelling
2nd type	Basic sciences	Physics; Chemistry; Biology	
3rd type	Applied sciences	Electronics; Software Engineering; etc.	
4th type	Environmental sciences	Geomatics science; Geographic science Cartographic science	Remote Sensing; Geographic Information System; Global Positioning Systems; Digital Photogrammetry; Geoinformatics; Programming; etc.

Table 3. Methodologies and Techniques in the context of science classification

Remote sensing and global positioning systems e.g. are methodologies or techniques that have similar fundamental bases, concepts and principles (all derived from *physical sciences*) like optics (which in these cases is employed through the application of electromagnetic spectrum at various wavelengths). Geographic information systems make use of digital tools (software) based upon the principles of logic and computer sciences. Such tools are used in *environmental sciences*, and also in cartography and geography. Since from an epistemological point of view the development of a science is closely linked to the establishment of *its own* postulates and rules, the increasing use of newly arisen methodologies and/or technologies cannot be considered as indicators for the development stage of the *environmental sciences.*

Cartography in the context of its technological development

For the newly established category of *environmental sciences* cartography is rather considered a technique, expedient or tool to achieve its objective and to display – and thus communicate - its results than a science of its own. In the case of geomatic sciences e.g. GPS, geo-information systems and remote sensing are nowadays essential assets to digital or automated cartography. They strongly support the capture, input, processing, analysis, presentation and application of geo-spatial data. For the treatment (in the widest sense of the word) of the constituents which compose both natural and man-shaped landscapes and for the representation of land at different scales, cartography is also fundamental, especially in *environmental sciences*.

The above mentioned are techniques, expedients or tools used for practical applications. Therefore they must not be considered within the context of the development of the *environmental sciences.* When cartographers use remote sensing, mostly this does not contribute to the advanced use of electromagnetics; when they apply photogrammetry this does not develop our knowledge in optics; or when they use geo-information systems they are mostly neither developing logic nor computer science. In all described situations the expert is applying tools to secure concrete objectives within his field of action. If she/he dives seriously deeper into the development of these subjects, she/he would no longer be pursuing cartography, and therefore not primarily be a cartographer by occupation but rather an optical physicist, a logic expert, or a computer scientist respectively.

With reference to the (“classical”) definition of cartography given at the beginning of the paper and the issues mentioned in the last paragraphs, cartography has to be investigated both in the context of its scientific dimension *and* its technological character. It is, however, a common belief that cartography has a scientific status *only* because it uses technologies which are based on sound principles stemming from *applied* or *basic sciences*. In epistemology the scientific status of a discipline is defined by its capacity to generate own concepts, postulates and principles, and not by the

development of the methodologies and/or technologies it applies (although these technologies derive from principles and laws of *basic sciences*).

The intension of this paper is to position cartography in the context of sciences, but for this, as already postulated by Koch (2002), it is a prerequisite that it is accepted within the scientific community as a science of its own. Also, it will be necessary to develop theories, laws and models in both *general* and *applied cartography.*

Conclusions

As a result of the attempt to determine the position of cartography in the general framework of sciences the following findings may be identified and/or conclusions drawn:

The widely accepted models of Ogrissek (1987) and Koch (1995) concerning the role of cartography in the context of sciences indicate *relations* between the scientific disciplines or their components and do not treat *hierarchical orders* existing among them. In the present paper this has been done by comparing the position of cartography with other sciences.
If - in the light of *neopositivistic epistemology* - the same view like on the methodology used in geography will be applied to cartography, one can claim that e.g. map projections also use postulates of *formal sciences* like mathematics and geometry. In contrast to geography, however, cartography makes a much more genuine and intensive use of and not only a simple reference to geometric basics. Due to this fact, it has to be stated that cartography, in spite of (still) being at a lower level than geography in terms of its theoretical development, uses postulates of *sciences of the first type,* i.e. the *formal sciences*. According the Harvey's "classical" structuring of sciences from 1969, *cartography* has to be assigned to the *sciences of the fourth type*, the *environmental sciences.*

So far, cartography has experienced only little theoretical development. In such cases methodologies and techniques are frequently mixed with a discipline's own scientific development, and technologies are thus considered as if they were genuine disciplinary knowledge.

Despite the comparatively meagre theoretical investigations carried out about cartography as a subject, since its official acknowledgement by UNESCO as a science of its own in 1949, it is currently the common understanding within the cartographic community that *cartography has a prominent scientific status* because it uses technologies, which are based on solid principles from *applied* or *basic sciences.*

In order to better understand the theoretical and technological dimensions of cartography it is necessary to further identify aspects of its identity as an independent science. Moreover, concepts, postulates and principles have to be developed which justify the status of cartography within the neopositivistic classification scheme of sciences. If cartography wants to reach a wide-accepted, more prominent scientific status, it needs, in addition to its well-developed and up-to-date methodology, to create its own updated epistemological basis.

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