review Article

Maps and cartography: Progress in international critical cartography/GIS research

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ABSTRACT

Map is the basic language of geography and an indispensable tool for spatial analysis. But for a long time, maps have been regarded as an objective and neutral scientific achievement. Inspired by critical geography, critical cartography/GIS came into being with the goal of clarifying the discourse embedded in cartographic practice. Power relationship challenges the untested assumption in map representation that is taken for granted. After more than 40 years of debate and running in, this research field has initially shown an outline, and critical cartography/GIS has roughly formed two research directions: the deconstruction path mainly starts from the identity of cartography subject and the process of map knowledge production, and analyzes the inseparable relationship between cartography and national governance and its internal power mechanism respectively; the construction path mainly relies on cooperative mapping and anti-mapping to realize the reproduction of map data. Domestic critical cartography/GIS research has just started, and it is necessary to continue to absorb the achievements of critical geography and carry out research in different historical periods. The deconstruction research of different types of maps also needs to strengthen the in-depth bridging between the construction path and the deconstruction path, and to be more open to the public. Impartial map application research, and actively apply the research results to social practice.

Keywords: Critical Cartography; GIS; Power; Knowledge Production; Collaborative Map-Ping; Inverse Mapping

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1. Introduction

Spatial analysis is one of the four traditions of geography, and map is an indispensable tool for spatial analysis, and its importance is self-evident. Harvey[1] pointed out that maps "are the structural pillars of all forms of geographical knowledge". However, in the 1970s, with the popularity of social critical theory, the focus of geographical research once shifted from space "entity" to "society space", and to the theoretical construction of non-entity space such as "space production". As a result, the geographical community about maps. The discussion of cartography and GIS is decreasing [2]. The political geography Committee of IGU (International Geographic Union) was founded by the world political map research group. Taylor[3] also pointed out in the article of the journal *Political Geography* commemorating cartographic master J. B. Harley that "maps are closely related to political geography", but maps are basically invisible in various political geography publications[4]. Correspondingly, on the other hand, under the guidance of "scientific epistemology", cartographers and GIS scholars are in politics, power, discourse

and post-colonial resistance are also collective aphasia[2]. However, many turns since the 1970s have also triggered a series of thoughts of geographers. Under the background of moving towards "hybrid geography"[5], critical cartography and critical GIS came into being, directly facing the production and use of maps. Words embedded in communication, power relations, challenge the untested assumption that is taken for granted in map representation, and question the way map thinks about space[2]. Traditional cartography overemphasizes the characteristics of "objectivity" in practical operation, which makes people who read maps and who are induced by deep-rooted cultural background or prejudice to accept it as the objective facts of space fail to see the inevitable interests; similarly, cartographers cannot see these interests, and even endanger cartographers themselves[6]. Critical cartography aims to reveal these "hidden cartographic agendas", that is, "as a tool of social space forces", so as to bridge the gap between technology-oriented map design and social power analysis.

At present, critical cartography/GIS has attracted extensive attention in the field of geography abroad. Scholars focus on the power relationship in map/GIS knowledge production, and analyze the possible biases and limitations in its practical application; we are also constantly developing new technical means to break through the traditional restrictions. Look for richer and diversified representation methods to build a more open and inclusive map. In contrast, domestic geography is still dominated by the "scientific" discourse, and a large number of studies use the spatial data collected through various ways uncritically, and are dedicated to the exploration of the "objective" spatial structure and mode. In this context, this paper summarizes the development process and research direction of critical cartography/GIS, with a view to drawing lessons from the current domestic map/GIS research.

Critical cartography and critical GIS overlap, but do not coincide. Critical GIS emphasizes GIS/scientific society as interactive spatial data visualization and analysis. Political meaning, and critical cartography refers to the critical reflection on the map and mapping process. How to distinguish them depends on people's understanding of the relationship between GIS and cartography. This paper does not attempt to strictly divide the two here, but focuses on the overlapping part of the two, that is, the mapping itself. Therefore, the combined concept expression of "critical cartography/GIS" is adopted.

2. Critical cartography/GIS development

2.1 Establishment of the status of "scientific" cartography

Human beings have a long history of making maps, but it was not until the 15th and 16th centuries that great changes began to take place in the methods of map making[7]. Around 1400, the rules of European cartography gradually gave way to the "scientific" cartography[8] composed of geometric principles from the narrative and symbolic significance emphasized in the middle ages. Space became a problem of the relationship between the sky and the earth, and the distance was in degrees. Triangles and geometric figures are calculated[9], and since then, the map has been regarded as objective, neutral scientific achievements. Cartography, as a scientific pursuit, is committed to answering how to best express spatial data, such as how to use new technology to present data, how to use color, and how to make maps more match people's thinking, and easier to read, etc.[10] By the 19th century, people not only focus on the presentation of geographical elements, but also pay attention to the correlation between the distribution of different geographical phenomena, that is, the research of spatial analysis has also appeared. These statistics and thematic maps are widely used in education. Social problems such as crime and disease[11,12]. In addition, various views on states and their legitimate occupation of territories are also written in scientific terms. People believe that natural reality can determine geopolitical arrangements[13]. Therefore, cartography is also closely combined with political geography.

After World War II, Robinson *et al.*[14] redefined cartography and systematically described the principles of map design; Bunge's[15] Theoretical Geography, published in 1966, declared that cartography is

the mathematics of geography; some scholars even believe that the development of GIS is to form "a complete and scientific new geography" provides the possibility[16]. However, in fact, the reflection on cartography/GIS has always existed, but it was not paid attention to in the early stage. The famous American political geographer, Spykman[17], spent a lot of space in geography of peace discussing the drawing of world maps and analyzing geopolitical metaphors under different projection methods; Lacoste[18] also pointed out, "map was and is the core of geography, and is a basic power tool. Map is a way of expressing space, which is convenient for the domination and control of space. Making maps is to serve the practical interests of the national machine". In 1974, Peters[19] also proposed that "the most popular projection method always exaggerates the area of higher latitudes (mainly the land area of the northern hemisphere), and the cost is not only part of the truth, but also the self-image of developing countries". "Most other projection methods have preconceived bias", they "look at Europe and North America through a magnifying glass, and then look at the rest of the world through a telescope"[20]. Peters[19] then proposed that the Peters-Gall projection method seeks to display countries around the world according to their actual surface area. However, although Peters' criticism points out the "subjectivity" of other maps, it is based on thinking that his own map is the most "objective".

2.2 GIS debate and critical cartography/GIS birth

In the era of rapid development of GIS, most human geographers were far away from the trend of positivism and critical rationalism, so they criticized GIS's attempt to unify geography as "scientific geography"[21], which led to a lasting debate between critical scholars and traditional GIS scholars, which can be roughly divided into three stages (**Table 1**). Although differences still exist, the epistemological basis of map/GIS has been basically unified, and a new research field has gradually taken shape.

The first stage of criticism believes that geography is an overly complex and diverse discipline, and that GIS is in danger of overwhelming post positivist methods, thus limiting the ability of geography to understand the world[25,32]. In addition, GIS embeds specific spatial concepts (especially geometric space) and specific reasoning forms (especially Boolean logic) to depict space as an independent grid, in which the social process is located, rather than Einstein or Leibniz's argument that space is a relationship, so that GIS cannot fully represent non-European spatial concepts and the communication rationality of daily life[33-35].

These criticisms caused the same sharp response of GIS experts, who found that these criticisms were too simplistic, too pessimistic and even paranoid, indicating that critical scholars lack understanding and experience of GIS. At the same time, they regard these criticisms as a negligible anger, because students and practitioners are increasingly interested in GIS[36]. Of course, at that time, within the cartographic community, Harley[8,11,37]. Monmonier[38], Wood[6] and other scholars have abandoned the ontology of taking maps as the product of "objective" and "science", and their works have produced quite a wide range of influence. However, Harley's specialty is the history of maps, more like a historical and cultural geographer; monmonier represents the humanist trend of thought in cartography; wood paid more attention to map art and was not a mainstream scholar at that time. In general, at this stage, critical geography and GIS formed an almost complete binary opposition.

By the end of 1990s, the scientific myth of map and GIS had been disintegrated inside. It was no longer regarded as a symbol of technology and instrumental rationality. On the contrary, it was a wrestling field of all kinds of power/knowledge. This does not mean that GIS is no longer useful. The reflection on data and technology has promoted the continuous exploration of the feasibility of qualitative and hybrid research in GIS[39,40]. With the development of more inclusive representation means and higher social sensitivity analysis methods, GIS has become more and more reflexive. In 2009, Tim Schwanen and Guan, in the journal *The Professional Geographer*, organized two consecutive issues (Volume 61, Issues 3 and 4) of *Critical Quantitative Geographies* column. In the same year, the journal

Cultural Geographies (Volume 16, Issue 2) also organized the "Special issue: Indigenous cartographies) column. In 2012, the Journal of *Cartographica: The International Journal for Geographic Information and Geovisualization* (Volume 47, Issue 2) organized a whole issue of "Indigenous Cartographies and Counter-Mapping" column. In 2018, *The*

Professional Geographer (Volume 70, Issue 1) organized a column of "Critical Data, Critical Technology" again. All these show the potential role that map/GIS may play in a broader field, and critical cartography/GIS has attracted continuous attention in the field of geography.

Table 1. Three stages and main features of the debate between critical geography and GIS

Stage division	Core content of the debate
1983–1993	In the first round of debate, GIS was labelled as "non intelligent" and assumed objective "positivism" by critical scholars, and its research was based on factual data rather than valuable information; GIS scholars responded strongly to it, saying that the other party lacked in-depth understanding of "science"[16,22,23]
1993–1998	In the second round of debate, the Cartesian geometric space that GIS relies too much on is still repeatedly emphasized. In addition, critics believe that it represents hegemonism, which also puts the society in danger of becoming a surveillance society; at the same time, the two sides of the dispute began to hold meetings together to bridge their differences Representative literature: [24,25]
1998–2001	In the third stage of the debate, both sides realized that GIS is not necessarily positivist, but can also be used for elastic non deterministic analysis. The debate between the two sides gradually gave way to how to jointly "reconstruct" a more socially responsible GIS Representative literature: [26–28]

Note: the data comes from references[2,16,21–31] with changes.

2.3 Critical cartography/GIS research field

After more than 30 years of development, critical cartography/GIS has gradually formed a relatively clear pedigree and context, and has promoted the intersection and integration of various sub disciplines to a certain extent (**Figure 1**). Scholars mainly reflect and question traditional cartography/GIS from the following two dimensions (**Table 2**): on the one hand, traditionally, countries and cartographic experts are reliable and effective data sources, but with the rise of geoweb and new spatial media, more and more "amateur" spatial data providers have formed a powerful "bottom-up" force, the "top-down" mode of knowledge production is changing rapidly (voluntarily or involuntarily); on the other hand, the traditional "scientific" mapping is considered to cover up the complex social reality with "objective facts" with the subjective prejudice of the cartographer, which is only a kind of discourse and practice. An object with disciplinary and social influence[43]. Scholars began to rethink the ontological basis of cartography, changing from understanding map representation to understanding map process. They were no longer keen to explore the essence of things, but focused on how things happen[44].

Therefore, the research work on this basis can be divided into two dimensions: deconstruction and construction. Scholars who criticize the background of geography focus on the deconstruction of maps, focusing on what specific group/knowledge/space concepts "privileges" have been given by the production of "scientific" maps since the 16th century, so as to "legitimize" national governance; how can suppressed and marginalized knowledge and "Aphasia" groups make national governance "ineffective". Scholars with the background of communication and control cartography/GIS focus on the reconstruction of the "problem" map. Although radical critics believe that due to the "non contextualization" of spatial analysis methods, the contradiction between empirical (positivist) spatial analysis methods and post structuralism is irreconcilable[45], the previous analysis shows that cartography and GIS can also be applied to multi-source data and multi-cultural. Open values and produce "situational knowledge". Based on this, the new concept of map/GIS. The exploration of new methods can show the spatial concept of the suppressed groups, and the qualitative data that cannot be represented by "scientific" maps can also be made up. The fallacy caused by the analysis of official data without consideration is also expected to be alleviated.
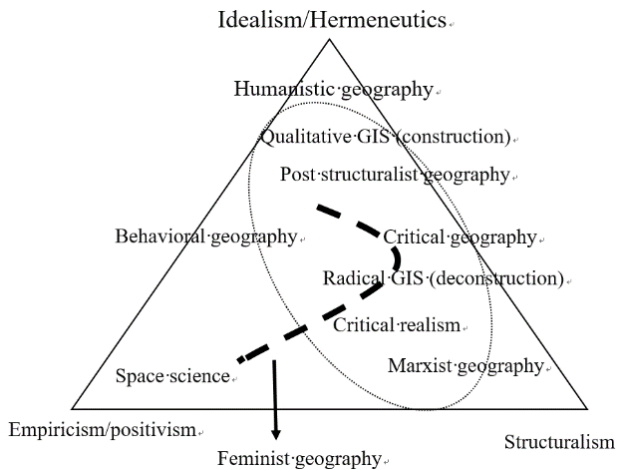
Figure 1. Opposition and integration of different schools of human geography.
Note: the data comes from Sheppard[36,41] and is modified according to Tang and Huang[42].

3. Deconstruct map/GIS: Break the dual dualism

The "orthodox" source of deconstructing maps comes from J. B. Harley. Since 1987, Harley has successively published a series of influential articles, which triggered a profound change in the epistemology of map essence in the academic community. Harley[37] believed that at that time, people still accepted the "facts" presented by map makers uncritically. In particular, people often tended to assume that cartographers undoubtedly engaged in a "scientific" or "objective" knowledge creation, which constituted a major obstacle to people's understanding of maps. Even the "scientific" map is not only the product of "the rules of geometric order and rational order", but also the product of "the norms and values of social order"; although "scientific" cartography strives to transform culture into nature and "naturalize" social reality, it is still a rhetorical discourse. Steps of mapping—selection. omit, simplify, classification. The creation of hierarchy and "symbolization"—are essentially rhetoric, both symbolizing the subjective purpose of human beings. In the "ordinary" scientific map, science itself becomes a metaphor. This kind of map contains a dimension of "symbolic realism", which is a statement of political authority and control[37].

Table 2. Analytical framework of critical cartography/GIS

Power performance	Scientific cartography/GIS	Critical cartography/GIS	
		Radical cartography/GIS (deconstruction)	Qualitative cartography/GIS (construction)
External power of maps: who owns the production and the right to disseminate and interpret maps?	"Top down" advocates the specialization of cartography technology and is committed to establishing cartography/GIS subject knowledge system	Expand the concept of "governance" to "cartography", and reveal the ubiquitous logic of national space governance behind professional cartographic knowledge	"Bottom up" advocates amateur public participation in cartographic practice, and is committed to the development and opening of various online geographic services and new space media
The inner power of map: map expression, whose space rights are claimed or covered up?	It is believed that map is an objective representation of space, and spatial information can be completely expressed through "scientific" language to advocate quantitative data	It is believed that any mapping process is a selective expression of objective reality Reveal which subjects' power is strengthened by the map and which groups' power is suppressed at the same time	Attach importance to artistic/non-scientific mapping and strengthen qualitative GIS. Counter mapping and other non-quantitative means

Therefore, the map is only one of the many ways that human beings view the world, and are far from the reality of the world, comprehensive mirror representation. According to Michel Foucault and Jacques Derrida, map is a "form of knowledge and power", and a basic medium of state power[8]. Therefore, instead of focusing on how the map reflects the theme, it is better to rethink how the map acts as a space. The products of places and fields, and how people shape the political identity of these spaces[46].

Harley[37] also pointed out that the power of maps is twofold. First of all, "internal power" or "epistemological power" determines the principles of cartography: what is considered a map in a specific context, how it is produced, and how space is represented. In this regard, the cognitive rules on the map determine the "type" space generated by a certain map making mode. Secondly, "external power"

or "cartographer power", which is realized by map makers and users. In short, epistemological power determines how to write space, and the identity of the cartographer determines who the author is, or can be. Obviously, the relationship between "epistemology" and "cartographer" has never been completely separated. In modern western society, maps have quickly become the key to maintaining state power. It is precisely because of the combination of the "scientific" expression of space and the dominant position of state institutions in cartography that scientific maps have become an important but opaque source of power[37,47].

The revelation of the dual power of maps is conducive to our understanding of the significant dual binary opposition between traditional and critical cartography/GIS in the analytical framework proposed in section 1.3. Among them, the external power involves the opposition between the cartographer's identity and the world outlook. The discussion of it mainly solves the problem of "why (need/should) is this/that" of the map; internal power involves the opposition between "science and non-science". Accordingly, the discussion of it focuses on the problem of "how to express this/that" in the map. The following will be elaborated from the perspectives of external power and internal power of map/cartography.

3.1 External power of maps: Cartography and national governance

Cartography is an indispensable part of national governance. The practice of life politics depends on the government's ability to locate its population in geospatial space[48], so as to shape the population as an "object" that can be effectively ruled by the state[49]. The most well-known and controversial use of maps is to shape the nation-state with clear geographical boundaries in the formation of the modern world system. Strandsbjerg[47] pointed out that the representation of territory in the form of maps is a necessary condition for the emergence of modern territorial order. He discussed how the transformation of cartography between 1450 and 1650 changed Denmark's spatial knowledge. Maps made the country construct itself as a spatial entity and claimed ownership of the whole territory. Similarly, Branch[50]

analyzed the role of maps in the formation of French territory; Winichakul[51] takes Thailand, the only country in Southeast Asia that has not been colonized, as an example to analyze how the map has built a modern nation-state in non-western countries and replaced the original geographical discourse. Below the national scale, the "scientific" power of cartography provides sufficient "national reasons". Martin[52] believes that the progress of capitalism is a progress in the sense of cartography, which is reflected not only in the institutionalization of investigation and control within the nation-state, but also in its economic expansion and annexation of other forms of economy; Hannah[53] showed how the U.S. government effectively maintained its control over its national territory by using census and political mapping through the study of the 1870 and 1880 U.S. censuses; Cramton[54] also showed that early French and British political economists obtained population information by drawing isoline maps of aggregated data, so as to provide information for national decision-making; therefore, the contour map was introduced into the "rationality of population/territory calculability", which became the core of modern government projects.

3.2 Inherent power of maps: Power/knowledge in Cartography

Mapping necessarily involves population, filtering of resource attributes, classification, selection of scale. From the perspective of life politics, Painter[55] pointed out that statistics, model, forecast, maps and charts are performative and illustrative: the choice and connection of variables. The drawing of boundaries and the formulation of assumptions have the effect of presenting some characteristics of the world at the expense of other factors.

The inherent power of cartography is first reflected in the differentiation of element attributes based on specific purposes. Screening and even shielding, and classification itself is also an expression of power relations. Harley[37] argues that the distinction between class and power is designed, embodied and legitimized by means of map symbols. The map symbols hierarchize the space through the rule of "the stronger, the more prominent", which is

often not deliberately done by the cartographer, but just reflects the fact that "the king is more important than the Baron's place, the castle is more important than the farmer's house, and the archbishop is more important than the high priest", which is taken for granted. Cartography uses its vocabulary accordingly, thus embodying a systematic social inequality. Wood[6] pointed out that even "neutral" things like topographic maps or road maps may be political: the silence and omission of maps (such as any non-motorized lanes or bicycle lanes, or any information about public transport) represent the privileges of cars to other commuting modes, so it is a deliberate (and political) choice. In spatial population statistics, the use of regions that follow the boundaries defined by the state to summarize data can "see" the population phenomenon, but it does not necessarily reflect the characteristics of the population under study [56], but strengthens the perspective of the state, causing a typical modifiable area unit problem (MAUP)[57], so that some social problems may be amplified, or covered up[56,58], etc.

4. Reconstruction map/GIS: Beyond absolute space cartography

More and more scholars have noticed that cartography and GIS may have reflexivity. In order to "restore" the critical potential of cartography/GIS, different scholars have explored two aspects: data production and representation.

4.1 Production of map data: Collaborative mapping

It is generally believed that collaborative cartography originated from indigenous cartography/mapping. As early as the 1960s, indigenous groups in Canada and Alaska in the United States began to practice indigenous cartography[59], expressing space through independent cartography, thus breaking through the limitations of official cartography to achieve the establishment of land

sovereignty, protection of local natural resources and inheritance of indigenous culture[60]. Later, this practice was also extended to other communities, forming a series of community mapping or participatory mapping projects. As Perkins[61] pointed out, since 1985, Britain has begun to promote the Parish Map Project to support local characteristics and local empowerment. By the 1990s, with the rise of digital media, (public) Participatory GIS, (P)PGIS[1] as a technical means was rapidly and widely used in the above projects[59,62]. After entering the era of Web 2.0, mapping technology and applications that support multiple users to edit content at the same time (OpenStreetMap, Wikimapia *et al.*) Make voluntary participation possible[63–65]. In addition, the cost of data storage is reduced, and social media applications and map services are further aggregated (Foursquare, Flickr *et al.*) and communication network. The development of infrastructure such as data centers makes it easier for individuals to generate and access geographic information through their own mobile devices, thereby realizing "geo-crowd-sourcing"[65]. "Geographic crowdsourcing" can be realized in two data forms: volunteered geographic information (VGI) and involunteered geographic information (iVGI). VGI refers to the way that users collaborate online with ordinary handheld GPS terminals. Open access to high-resolution remote sensing images and personal spatial cognition based on geographical knowledge, create, edit, administration. geographic information maintained[66]; iVGI records locations and activities through personal mobile devices and external devices[67]. Miller[68] believes that the first real "geographic crowdsourcing" collaborative mapping in the era of Web 2.0 may be the first Google map aggregation (mash-up) created by volunteers in August 2005. The purpose is to enable citizens of New Orleans to share information to better cope with the great damage caused by Hurricane Katrina.

In this context, collaborative mapping supported by PPGIS[2] is not only a supplement to

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[1]Although some scholars believe that PGIS focuses more on the "technical level" and is mostly used in backward areas, PPGIS pays more attention to "participation in decision-making" and is mainly used in developed areas; but generally speaking, there is no clear distinction between PGIS and PPGIS in academic definitions, which are collectively referred to as PPGIS.

[2]In this research field, local mapping, community mapping, participatory mapping and other terms are still used by different scholars, and there is no common saying. However, the starting points of different studies are basically the same, hereinafter referred to as collaborative mapping.

official map data, but also is gradually reconstructing geographical reality. Leszczynski[69] pointed out that although national institutions are still the source of map data, the increasing participation of citizens and the private sector is releasing signals to replace the state as the main authoritative source. Elwood *et al.*[70] found in the survey of 99 VGI plans that nearly 2/3 of these plans were initiated by for-profit institutions, and only 7% were initiated by the government; at present, the state is largely limited to acting as a regulator and an intermediary between citizens and the private sector. Local residents in some communities in the United States are becoming "mapping agencies", using handheld devices such as GPS and mobile phones to collect and map community data, and report community problems such as crime to local authorities[71]; in Canada, some indigenous communities are using geo social media to advance their political agendas, and they are working with research institutions to develop collaborative online mapping applications to obtain ownership of their projects[72]. In this emerging model, citizens are increasingly positioned as "prosumers", who are both consumers of free space products and free producers of cyberspace data[73].

However, some scholars still have reservations about whether collaborative mapping based on geographic social media has actually reduced social and historical differences. The map content collectively produced through social media is still, to a large extent, the expression of the values of a few contributors with technical capabilities[60], that is, "rich, strong, educated, and most of them are over representation of male elite"[74]. It is more a transformation of the existing power structure than a real resistance[60].

4.2 Representation of map data: Counter mapping of suppressed groups

Compared with collaborative mapping, anti-mapping is more revolutionary. In its way of thinking, the groups ignored by the mainstream are no longer "passive" data sources, but can "actively" grasp the map representation. Anti-mapping usually relies on anthropological approaches, cognitive cartography, map biographies and village-level meetings, etc. to present indigenous knowledge through qualitative means rather than placing it in mainstream discourse for interpretation[75]. Cognitive maps, such as sketch mapping, have been used in boundary perception, as well as personal, specific local experience has been applied in geographical research[76]. For example, Ben-Ze'ev[77] studied how Israeli Jewish college students and Palestinian Arab college students experience their surroundings through hand-painted sketches; Gieseking[78] conducted interviews and mental map exercises on 32 female students in a school to understand women's gender identity and power experience after entering the school; Hirt[79] believes that by drawing dreams and practical maps of dreams, people can consider god, spirit and the existence of non-human actors in indigenous space concepts; Sletto[80] further explored the identity formation process of indigenous communities. Social construction of local landscape, the relationship between memory and map; Mekdjian[81] and Fischer *et al.*[82] have also been working with artists and asylum seekers to help them draw personal maps of their immigration experiences and memories. In addition, some innovative cartographic languages are also used to represent indigenous cultural knowledge, such as animation, sound and smell maps represent spirit and imaginary geography, etc.[83,84]

Applying grounded theory to GIS can be regarded as a breakthrough in the field of anti-mapping, which leads more and more scholars to pay attention to qualitative GIS. Some researchers believe that coding, the core of grounded theory, is a process of data simplification and data analysis, which is similar to the analysis process of GIS. Both of them involve dealing with data rich environments and understanding patterns and processes[85]. Based on this, Guan[27] took the lead in combining computer-aided qualitative data analysis software (CAQDAS) with GIS development and design platform to study the spatiotemporal path of African American women in Portland; supplemented by qualitative narrative data, this paper studies the life trajectory of Islamic women in Columbus after the 9·11 incident[86,87].

Hawthorne et al.[88] used Q method[3] to convert residents' emotional data "quantitatively", and studied the neighborhood avoidance effect of railway development on the community; Pavlovskaya[89] used ethnographic data to draw a comprehensive economic map of post socialist cities, which will informally employ wage income, informal and unpaid goods and services flowing within households are also included in the income category of residents; Knigge et al.[85] combined GIS based spatial analysis and qualitative data to conduct a comprehensive study of Buffalo community garden, and discussed the social significance of community garden, as well as the economic and demographic environment of the garden; Kim[90] further conceptualized the spatial experience of relevant groups by applying the grounded theory to the research on the debate of street vendors on the use of sidewalk space in Ho Chi Minh City.

In addition to anti mapping, some GIS scholars have also proposed more "technical" innovations, such as the re-emphasis on cartogram[91]; using dasymetric mapping to solve the inconsistency between the actual boundary of spatial element distribution and the boundary of existing statistical units (such as census units)[92,93], which promotes the solution of MAUP to a certain extent; in addition, some scholars have explored the uncertain geographic context problem (UGCoP) related to MAUP, identifying and describing geographic units that can represent the real environment of individual daily activities[94]. Although it is still a relatively new research field, it also shows that critical cartography/GIS research has begun from the production of data, representation is further analyzed and explained.

5. Summary and outlook

As a social representation, map is embedded in various power relations and transformed into a discourse power to regulate individual behavior and control group practice[95]. Therefore, all maps are the "subjective" expression of cartographers' cognition of the world. However, "scientific" cartography often claims to represent the "objective" world, which leads to ubiquitous "cartographic anxiety"[96]. Since the 1980s, critical geographers took the lead in questioning the transcendental "objectivity" assumption of data in spatial analysis, which immediately triggered the criticism and response of GIS scholars. After many debates, critical geography and GIS gradually moved towards mutual understanding and compromise, and began to integrate into a new research field—critical cartography/GIS, and formed two research directions of deconstruction and construction at the same time. The deconstruction path mainly follows structuralism and postmodern methodology extends "governance" to "cartography". Starting from the identity of cartographic subject and the process of map knowledge production, it analyzes its inseparable relationship with national governance and its internal power mechanism; the construction path absorbs the essence of humanistic methodology and tries to combine it with positivist methodology, mainly with the help of cooperative mapping and anti-mapping methods to realize the new production and new representation of map data.

In contrast to Chinese geography, critical cartography/GIS is a field that needs to be developed. Transportation, social media, big data such as POI[97] are increasingly popular in domestic urban research, but these data are mostly used uncritically as the "objective" essence of space. At present, China's human geography also shows some signs of the sprouting of critical cartography/GIS research, such as An et al.[95] revealed the micro power operation mechanism of the map discourse system with the help of social representation theory; some scholars call for the introduction of the concept of "mixing" to break the distinction between "space analysis" geography and "social culture" geography[98]; or emphasize the production of geographical knowledge or ideological innovation research based on locality to realize the combination of human geography and GIS[99], how light intensity, etc.[100,101] analyzed the special impact of the choice of map projection on global geopolitical analysis, as well as the transformation of American geostrategic space concept during World War II. In addition, thanks to the cooperation with domestic human geography scholars, the

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[3]A factor analysis method, which aims to find the commonness of views from different, subjectively ordered text statements or

pictures.

exploration of UGCoP has also received some empirical evidence in domestic cities[94,102]. In short, domestic critical cartography/GIS research has just started, but the personal attribute geographic information provided by various rich big data platforms, especially location-based services (LBS), is still a rare advantage[103]. The combination of humanistic methodology and positivism should become the general direction of domestic critical cartography/GIS development in the future.

Specifically, first of all, continue to absorb the achievements of critical geography (especially in the fields of social, cultural, political geography), it integrates the theoretical perspectives of relevant disciplines to carry out different historical periods. Research on the deconstruction of different types of maps. This includes not only the reinterpretation of power/knowledge in the map, but also the empirical research on the micro-power mechanism and operation of capital, culture and other specific cases[1]. Secondly, strengthen the in-depth bridging of the construction path and the deconstruction path, and run critical thinking through the whole process of research. Finally, we need to emphasize the public service orientation of research, carry out research for social applications, and actively participate in the social practice of research results. Thatcher[104] put forward the concept of "volunteer information services" and believed that VGI should be used to serve the people by improving the coordination of field operations. "Ushahidi"[4] has made a useful exploration in this regard. It not only collects geospatial data from the crowd (i.e. "crowd-sourcing"), but also returns this information to the crowd, i.e. "geo-crowdfeeding"[105], which is a very academic application example worthy of reference by geographers. In addition, PPGIS itself is more widely used in planning practice as an application technology. It is hoped that the vigorous development of critical cartography/GIS research will help geographers get out of the ivory tower. Going deep into the field and directly participating in social space practice brings more enlightenment and motivation.

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[4]A non-profit crisis early warning platform created by a Kenyan team combines social activities, citizen news and geospatial information, and uses the concept of "crowdsourcing" to promote social activities and public responsibility.

Conflict of interest

The authors declare no conflict of interest.

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