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METACARTOGRAPHY OF A. ASLANIKASHVILI AND RELATIONAL CARTOGRAPHY

ABSTRACT

Relational cartography is defined as the coordinated arts, sciences and technologies of making and using relations in cartographic systems and between cartographic systems. It is orthogonal to the paradigms of cartography, which research subject is map. The article describes the influence of A. Aslanikashvili's metacartography (hereinafter Metacartography) on the main components of relational cartography based on patterns (hereafter Relational Cartography or RelCa) as a science: inquiry domain (research subject), knowledge about the research subject, and methodology for acquisition new knowledge about the research subject. When considering the research subjects, the cases of coincidence of specific spaces of Metacartography and relational spaces and spatial systems of RelCa are described. It is proved that the main influence of Metacartography on knowledge of the RelCa research subject is the cartographic justification of the presence and correctness of epistemological relations in and between cartographic systems (and their originals in actuality). It is shown that the cartographic method of cognition of the Metacartography research subject is the basis of specialized cartographic methods of cognition of RelCa spatial systems.

The main differences between Metacartography and RelCa are the need to extend the RelCa research subject caused by the needs of modern cartographic practice. It leads to the extension of knowledge about the research subject, as well as to the corresponding development of methodology for acquisition new knowledge about the RelCa research subject. It has been suggested that coordinating one of the Subject cartographies with RelCa will allow creation of System Cartography. Such System Cartography will finally be a theory of cartography that will allow cartography to emerge from a constant crisis. In addition, practitioners will receive scientific explanations and justification for the necessary tools to deal with new cartographic phenomena.

KEYWORDS: relational cartography, metacartography, relational space, epistemological relations, cartographic method

INTRODUCTION

The development of cartography on the territory of the former Soviet Union has a big history and deserves special attention. It is worth mentioning the majestic figures who brought important thoughts to its essence and progressive development: K. Salishchev, V. Sukhov, M. Baranskiy, A. Preobrazhensky, M. Nikishov, I. Zarutskaya, V. Shotsky, O. Pavlov, Yu. Pospelov, G. Meshcheryakov, O. Evteyev, L. Bogomolov, A. Berlyant, O. Vasmut, S. Serbenyuk, O. Martynenko, A. Kharchenko, A. Zolovsky and many others. For quite some time the development of Soviet cartography formed a school that recognized, as the main, a paradigm of cartography, called "kartovedeniye" or "map science". Its leader was K. Salishchev. And here are two personalities appeared in the calm course of cartography development. Their works have led to wide discussions about the essence of cartography. These are works such as [*Aslanikashvili,* 1973; 1974; 1978; *Liuty,* 1981; 1988; 1989] et al. More about them further — but let's give A. Liuty's statement from his doctoral dissertation in 1989, where he developed the ideas of A. Aslanikashvili's language of map: "The aim of the reasearch is to develop a new ontological concept of the language

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of map as an objective phenomenon, identify the main features of its structure, functions and relations, lay the foundations of its theory and, based on this, rethink the material developed in cartography, develop a language-semiotic approach to understanding cartography, a new conceptual scheme of science as a system of disciplines, to develop and expand the program of its research activities taking into account the achievements of scientific and technological progress".

Discussions on the works of A. Aslanikashvili and A. Liuty were quite sharp and were held in various scientific forums. And the defense of A. Liuty's dissertation takes place in Kiev, not in Moscow. The thoughts of A. Aslanikashvili and A. Liuty actually formed new ideas about the essence of cartography, but they are not dogma. Therefore, there is a need to consider further ways of developing cartography.

The first theoretical and practical results from Pattern-Based Relational Cartography were published in Ukrainian in the monograph [*Chabaniuk*, 2018] and abbreviated in English — in the article [*Chabaniuk, Rudenko,* 2019]. Since no other relational cartography has been created yet, we refer to this paradigm simply as RelCa or Relational Cartography (in capital letters), without indicating its pattern basis. RelCa essential prerequisites are results from three scientific disciplines: General Systems Theory (Systemology), Computer Science and Cartography. To clarify the cartographic prerequisites, we use the definition of cartography by the International Cartographic Association (ICA) as a discipline that deals with the art, science and technology of making and using maps (https://icaci.org/mission/, accessed 2019–oct–12). A map is defined there as a symbolised representation of geographical reality, representing selected features or characteristics, resulting from the creative effort of its author's execution of choices, and is designed for use when spatial relationships are of primary relevance.

D. Sui, J. Holt [2008] distinguish the following three main "traditions" of cartography after the Second World War in accordance with three different conceptualizations of the essence of the map: (1) communicative/cognitive (map as image); (2) analytical (map as a model or means of calculation); and (3) critical (map as concept, intent, or social construction). A. Berlyant [1996] also identifies three major "concepts" of cartography. One concept is called communicative and is in line with the communicative/cognitive tradition [*Sui, Holt,* 2008]. Another concept is called model-cognitive. It is possible to find its common features with an analytical tradition [*Sui, Holt,* 2008]. Thus, A. Berlant defines cartography in the model-cognitive concept as the science of cognition of reality through cartographic modeling, and the map as the figurative-sign model of reality. Only the third concept of [*Berlyant,* 1996] — language — has anything clearly in common with either the critical or other traditions [*Sui, Holt,* 2008].

The reason for the difference between the language concept and the rest of cartographic paradigms (the term "paradigm" is the unification of the terms "tradition", "concept" and "paradigm"), in our opinion, lies in the difference between the research subjects. We call the paradigms of cartography, which are researching the map, as subject and classical. Accordingly, the language paradigm is not subject, since its main research subject is language of map, not the map. Interestingly, A. Berlyant [1996, fig. 3] included in the language paradigm the metacartographies of W. Bunge and A. Aslanikashvili. From the viewpoint of the cartographic "non-subjectivity" of these paradigms, this is the right action, since the research subject of these metacartographies is wider than the map. However, the research subject of metacartography is much broader than the research subject of the language paradigm, so inclusion by A. Berlyant the metacartographies in the language paradigm [Berlyant, 1996] is a controversial action from our point. The language paradigm is primarily related to the works of A. Liuty. The controversy of including metacartographies in the language paradigm is proved by the results of this paper, although this is not significant at present.

In particular, we will show why, of all these non-substantive cartographies (W. Bunge, A. Aslanikashvili, A. Liuty), A. Aslanikashvili metacartography is the most important cartographic prerequisite of Relational Cartography at the moment. To do this, we consider the impact of metacartography on the three major components of Relational Cartography, which according to [*Klir*, 1985] as for each science are:

- a **domain** of inquiry. Without going into further explanations, we often use the partial term and the notion of "research subject";
- a body of **knowledge** regarding the domain (subject);
- a **methodology** (a coherent collection of methods) for the acquisition of new knowledge within the domain (subject) as well as utilization of the knowledge for dealing with problems relevant to the domain (subject).

The condition "at the moment" is used above, since we assume that with the development of Relational Cartography, the language paradigm will have more impact on it. The metacartography of W. Bunge and A. Aslanikashvili cannot be compared, since [*Bunge*, 1967] considered theoretical geography and metacartography in his monograph devoted only one chapter. A. Aslanikashvili gave a full statement of metacartography, which still remains not only theoretically and practically useful, but also necessary. To highlight the A. Aslanikashvili's metacartography we will write Metacartography (in capital letter).

To complete this small survey of cartographic paradigms, let us note that geo-visualization in the West [*Cauvin et al.*, 2010] and geoinformation cartography in the post-Soviet space [*Berlyant*, 1996] are considered to be the dominant ones in the 21st century (about last one at least in Ukraine see [*Lyashenko, Kozachenko*, 2011]). However, we cannot treat them as scientific paradigms. Yes, [*Berlyant*, 1996, p. 33] states that "the geoinformation paradigm (concept) integrates, on the one hand, the idea of the map as a model with unique epistemological properties and powerful heuristic potential, and on the other — as a means of accumulation, transformation and transmission of information. And the cartographic models themselves appear in GIS as some geoinformation layers (or combinations of layers) that exist in digital or figurative graphic forms, and often — in conjunction with other images".

A. Berlyant [1996, fig. 3] considers the sequential divergence, convergence and, finally, integration of all three dominant paradigms of cartography, but the above quotation addresses the integration of model-cognitive and communicative paradigms only. It is unclear whether it integrates the language paradigm, and if so, how? This is why, in the context of the geoinformation paradigm, most authors are concerned with geoinformation mapping - program-driven making and using of maps based on GIS and bases of geographic (geological, ecological, socio-economic, etc.) knowledge [*Lurie*, 2008; *Lyashenko, Kozachenko*, 2011]. By the way, A. Berlyant [2006] quotes the same one already mentioned [*Berlyant*, 1996, fig. 3] scheme of divergence, convergence, and integration of cartography using 30 works on the theory of cartography, as well as the same description of the geoinformation paradigm. However, he acknowledges [*Berlyant*, 2006, p. 30–31], that the outstanding Slovak cartographer J. Pravda used the same 30 works on the theory of cartography and developed the idea of divergence of cartography.

The situation with the geo-visualization paradigm is not even better — so far it is a set of popular information technologies, which have little to do with the theory of cartography. That is why R. Roth stated the next crisis of (Western) cartography in his work [*Roth*, 2011] and suggested as an exit the integration of Western theoretical paradigms and called it a "growth perspective". A very important theoretical "complement" to the growth perspective is the cartographic interactivity, developed by R. Roth and his supporters. Nevertheless, R. Roth's approach to the crisis is essentially the same as that of A. Berlyant. Below, this approach is defined as analytical, and it differs significantly from the system approach applied by A. Aslanikashvili.

MATERIALS AND METHODS OF THE RESEARCHES

The materials of the research are constructs of physical and/or abstract components of two scientific paradigms: Relational Cartography and Metacartography. The components are: 1) inquiry domain (research subject), 2) body of knowledge of the domain (subject), 3) methodology for the acquisition of new knowledge within the domain (subject).

In each of two scientific paradigms main constructs of the research (as parts of materials) are three types of spatial systems: 1) in reality — relational spaces or spatial systems in RelCa and concrete spaces in Metacartography, 2) in information systems modeling space — spatial information systems in RelCa or ideal maps in Metacartography, 3) in general systems modeling space — spatial general systems in RelCa and no constructs in Metacartography.

We have used all three main inference modes in the research: abduction, deduction and induction. "Abductive reasoning is a form of inference that starts with data describing something and ends with a hypothesis that best explains the data. … Deduction proves that something must be, inductive reasoning shows that something is, while abduction merely suggests that something may be. Conclusions based on abductive reasoning are more tentative those based on deduction and induction" [*Miller*, 2010]. In this article main inference mode is induction and its analogy method [*Holyoak, Morrison*, 2012].

RESULTS OF RESEARCHES AND THEIR DISCUSSION

<u>Analogies of research subjects (inquiry domains) of RelCa and Metacartography</u>

The system is generally defined as the pair S = (A, R), where A is the set of elements, and R is the set of relations between elements of the set A that form a unity or organic whole [*Klir*, 1985]. Relational space is the view of space as the product of relations between entities. Space in this view arises at the same time as entities in it, which contrast with absolute space [*Cresswell*, 2013]. That is, a relational space can be represented by a spatial system.

G. Klir [1985] introduces specific classes of ordered pairs (A, R) related to conscious problems. These classes can be introduced using one of two fundamental criteria, focusing on systems based on specific properties: (a) things; (b) relations.

Criterion (b) leads to fundamentally different classes of systems, each characterized by a particular kind of relation without fixing any kind of thing on which the relations are determined. This classification is primarily concerned with processing rather than data collection and, thus, mainly its basis is theoretical. The largest classes of systems by criterion (b) are those that characterize different epistemological levels, that is, levels of knowledge regarding the phenomena under consideration.

The notion "relation" in systemology includes the whole set of related concepts, such as constraint, structure, information, organization, cohesion, interaction, coupling, linkage, interconnection, dependence, correlation, sample, **pattern**[1] etc. [*Klir*, 1985].

If we use the G. Klir's classification of systems, the Relational Cartography is orthogonal to the subject cartographies shown in Fig. 1. In the real world, we are interested in relational spaces or their spatial systems. However, in the current version of Relational Cartography, which we call classic, we study relations with spatial systems, which are prototypes of (classical) cartographic systems. The cartographic system is defined as a pair S=A×R or S=(A, R), where A is the set of elements among which there are maps, and R is the set of relations between the elements of the set A that form a unity or organic whole. Then it is simplified to say that:

- Subject cartography studies the properties of elements **a** of the set **A={a|a∈A}**;
- Relational cartography studies the properties of the relations **r** of the set **R={r|r∈R}** (and their images and originals);
- System cartography studies the properties of the systems **S=(A, R)** (and their images and originals).

Mentioned here **System** (or Geomatic or simply) Cartography is defined as the coordinated and uncoordinated arts, sciences and technologies of making and using maps, cartographic relations, and cartographic systems. A theoretically and practically useful System Cartography can be obtained by coordinating some Subject Cartography (eg Analytical) with RelCa.

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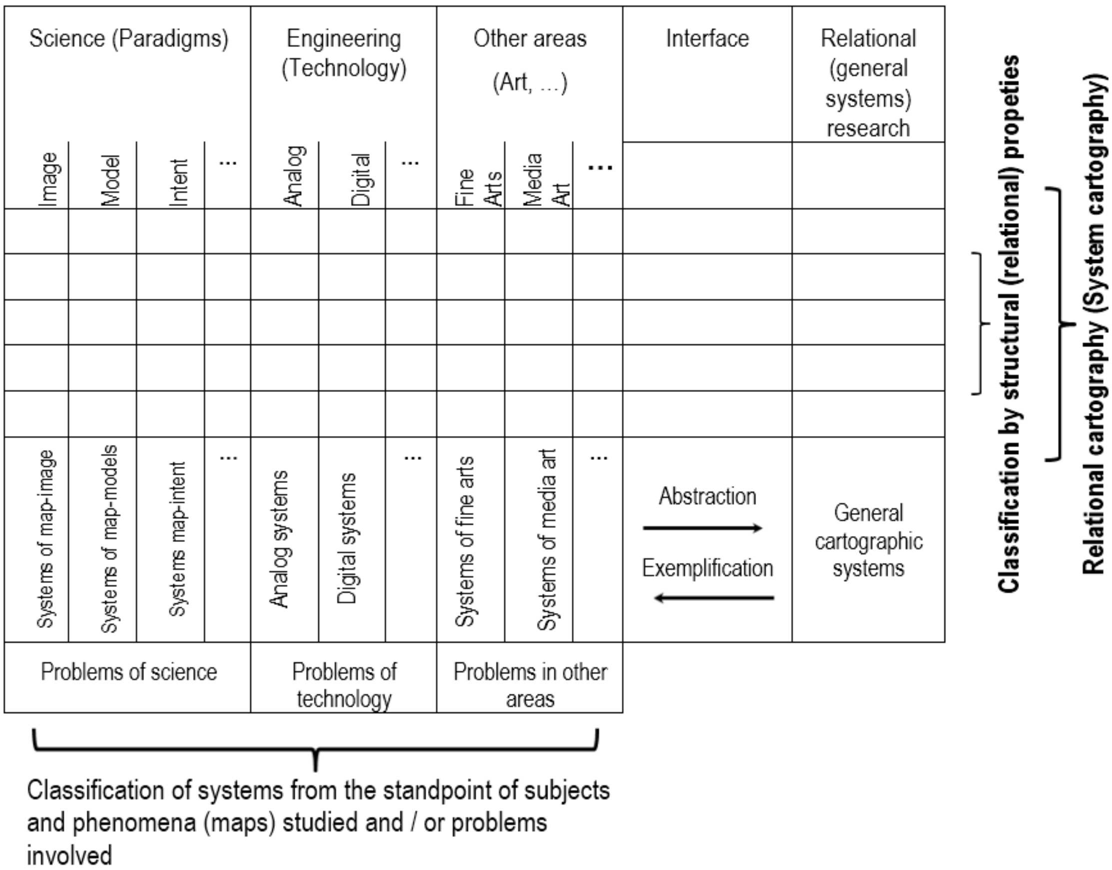

Fig. 1. Two ways to classify (cartographic) systems.
RelCa orthogonality to subject cartographies

For some fixed point in time, the RelCa inquiry domain (research subject) is shown in fig. 2. We are interested in the so-called epistemological and transformational relations that exist between and in the systems of four kinds (fig. 2):

1. **Real-world systems.** These systems are called geographic systems (geo-systems) or spatial systems (spa-systems). Geographical (spatial) system is defined as an ordered pair (A, R), where A is the set of things, among which are geographical (spatial) and R is the set of relations between elements of set A that form the unity or the organic whole. The term “geo-system” is left for synchronization with physical geography and topography.
2. **One-dimensional spatial (information) systems (1-dim Sp(I)S)**. These are the Sp(I)S, that exist in cartography at the moment: electronic atlases (EA), atlas information systems (AtIS), and carto-information systems (CIS). They are also called as Subject or Classical SpIS. We taken (information) in brackets (I), because SpS here can be non-informational. The example is analogue SpS.
3. **Two-dimensional spatial (information) systems (2-dim Sp(I)S)**. These are the Sp(I)S (remark about (I) is also true here), constructed (modeled) and studied in the Relational Cartography. They have a non-empty intersection with one-dimensional SpIS (fig. 2). It means that some classical SpIS are or can be elements of two-dimensional SpIS. In fig. 2 Sp(I)S are shown in the rectangle of (extended) IS. It means that all Sp(I)S in this work are kinds of IS, studied in computer science. Already acquired knowledge of these systems is used. The “extension” notion of both IS and SpIS is fundamental for this work understanding.
4. **Spatial general systems**. This is the SpS, obtained by abstracting of two-dimensional SpIS. In such way general systems are constructed in [*van Gigch*, 1991] or in systemology of [*Klir*, 1985]. It is possible to do the opposite and construct a SpIS from the inquiring systems

[*van Gigch*, 1991]. We showed the informal relations among strata and inquiring systems [ibid] with similar constructions from two-dimensional SpIS, and through them with the systems of the physical, abstract-physical and abstract worlds of the actuality from the left on fig. 2.

SpIS in a broader (extended) sense (SpISb) is an adaptation of the term "information system in a broader sense" [*Falkenberg*, *Lindgreen*, 1989] and is defined as the totality of all formal and informal representations of data, including spatial, and processing activity within an organization, including the associated communication, both internally and with the outside world. E. Falkenberg, P. Lindgreen [1989] define IS in the narrow sense (ISn) as a computerbased subsystems, intended to provide recording and supporting services for organizational operation and management. This ISn definition can be used for definition of SpISn.

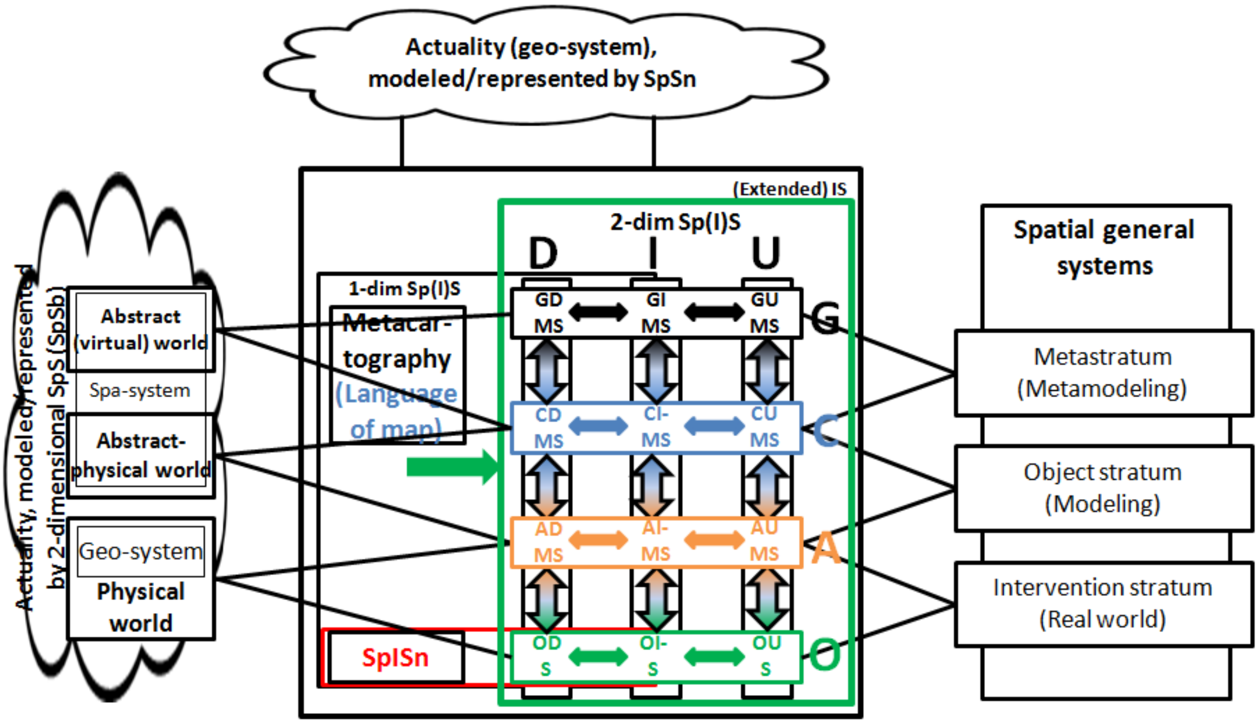

Fig. 2. Relational cartography inquiry domain (see relations)

Two variants of actuality, modeled or represented by SpIS, are shown on fig. 2. The first variant is shown from above. This is actuality — spatial system in narrow sense (SpSn), modeled or represented by one-dimensional SpIS. In this case the goal of developer is operational elements, SpISn. These systems can be called "map-centric" because their main part is map. As a rule, the developers of these systems pay little attention to the elements of the higher strata. In the RelCa the main goal of development is SpISb. In this case we are dealing with two-dimensional SpIS. As substantial addition to direct modeling of physical world we are using additional knowledge of the upper strata of these systems, which are the models/representations of abstract-physical and abstract worlds or spatial systems, determined in the second variant of actuality to the left side on fig. 2.

Let us explain the elements of the green rectangle in fig. 2, which is designated "2–dim Sp(I)S" and named above as the main purpose of RelCa modeling. In fact, one of the main results of RelCa is shown — the Conceptual Framework (CoFr) of the spatial system S, also called the system under study sus. Sus can change. In particular, it can be EA, AtIS, CIS and the like. First, let's explain the abbreviations:

- The letters D, I, U on the top indicate the CoFr levels: D — Datalogics (Datalogical), I — Infologics (Infological), U — Usagelogics (Organizational). The letters G, C, A, O on the right indicate CoFr strata: G — General, C — Conceptual, A — Application, O — Operational.
- XYMS, where X = D, I, U; Y = G, C, A, O, stands for XY M(odel) of S(us). For example, DCMS stands for Datalogical (D) Conceptual (C) Model (M) of System (S — sus).

To conclude this section, we present some quotations from the monograph [*Aslanikashvili*, 1974], which confirm the change of the research subject in Metacartography from a map to a **concrete space**. We believe that the quotations do not distort the meaning of the author. In any case, cyrillic-speaking cartographers can check the following quotes in the original:

1. **The second of the three explanations for the lack of proponents of traditional (subject) cartography interest in the philosophical category of space–time.** In the cartographic literature, the idea that recognizes geographical maps as the cognition subject of cartography is so widespread and persistent that it has been accepted almost as official and unconditional. In this regard, the need for a philosophical category that could penetrate in the theory of cartography only through the conceptual definition of the true cognition subject was neglected [*Aslanikashvili*, 1974, p. 14]. In fact, this is an actual and now the explanation of why the research subject of cartography is a map.

2. **The first of four provisions in the monograph proved.** Cartography, as a science, has as its cognition subject of the objectively existing order of the mutual placement (**concrete space**) of material subjects and phenomena — natural and social, as well as the change in the time of this order (concrete space). Reflecting the concrete space of the investigated reality and its change over time, this science identifies and "maps" the spatial structures and patterns of complex spatial systems of interacting subjects and phenomena in their dynamics. However, it does not explain them, because it is a matter of the relevant special sciences [*Aslanikashvili*, 1974, p. 7].

3. **The term "object" is replaced by "entity".** The symbolic expression of an ideal **concrete space** is defined as $R_{S(t)}(S_{sis}, e_1, e_2, e_3,\ldots, e_n)$, where R is a relation; S — space (spatium); sis — system (system); S_{sis} is a spatial system of reference (more precisely, a coordinate system of a spatial system of reference as a mathematical expression of its physical meaning); t — time (tempus); S(t) — space at a particular moment or time interval; $e_1, e_2, e_3,\ldots, e_n$ — the entities of actuality with its material essence, qualitative and quantitative certainty and its own structure. Such is the structure of any existing concrete space, and therefore the cognition subject of cartography. The ideal concrete space is the spatial relation of the spatial system of reference and the investigated entities of actuality (at some point or time interval) [*Aslanikashvili*, 1974, p. 39].

Since A. Aslanikashvili does not limit the values of the entities $e_1, e_2, e_3, \ldots, e_n$, and RelCa considers arbitrary physical, abstract-physical and abstract worlds and modeling/representing them spatial systems, we can assume that the research domains of two scientific paradigms — Metacartography and RelCa — in general coincide.

<u>Analogies of epistemological relations of RelCa and Metacartography</u>

Despite the almost half a century of age of the monographs [Aslanikashvili, 1968, 1974], we consider them not only still relevant but also necessary for the entire cartographic community, both Cyrillic and other languages. In doing so, we take into account the current state of cartographic theory, for which we have conclusive evidence of its ongoing crisis. Therefore, we consider the most important for the cartography to be the epistemological (or gnoseological) results of A. Aslanikashvili. In this section we will explain what is specifically meant. However, we draw the attention of the reader to the following facts, which have occurred over the last 50 years and which only increase the need to become acquainted with the works of A. Aslanikashvili in all major languages of the world cartographic community:

1. A. Aslanikashvili's monographs were published in the conditions when the main paradigms of cartography were mostly adopted by paper maps. There were no cartographic

electronic products-systems in general. This is not even about GIS, which developed later. Systems products such as atlases were mostly paper. In recent years, electronic cartographic products have emerged that cannot be called maps. Some examples are: 1) Electronic Atlases, 2) Google Maps Platform (Google Maps Platform https://cloud.google.com/maps-platform/, 2019-sep-29), 3) European Location Platform, http://elf.maps.arcgis.com/home/index.html, 2019-sep-29), 4) SwissAtlasPlatform [*Sieber et al.*, 2011]), 5) and others. That is, the question of changing the research subject of cartography is no longer a purely theoretical question. Changes to the research subject now need practice.

2. Undoubtedly, the advent of widespread access in the middle of the last decade, initially Google Maps and then the Google Maps Platform were a revolutionary change in information technology (in RelCa terminology — cartographic Datalogics) among others from Web 1.0 to Web 2.0. However, there were no significant changes in cartographic Infologics. Even more — the geoinformation disputes of the end of the last century actually ended when the layered approach was opposed to the object approach. Now, thanks to publicly available maps and geo-platforms, a layered approach is much closer to the concept of the map and its layers than the object one.

3. Here is also the conclusion from the paragraph "4.9.2 KIS: Cartographic Information System — (short) episode (?)" [*Azocar, Buchroithner,* 2014]: Maybe, the whole epistemological genesis of cartography in the following years[1] would have changed if the cartographic community would have put more emphases on KIS instead of GIS and on the final products, i.e. the maps than on the databases and methodologies behind them, i.e. the system architecture. In particular in the Anglo-American world, however, at this time the GIS freakiness was overruling the importance of the final outcomes, the geovisualisations. Thus, the strange situation occurred …, that, the terminology, the technologies, and methods ruled out the actual target or "desired object", the maps. That is, the issue of cartography development is still as relevant as it was 20 years ago. And GIS enthusiasm is purely technological.

J. van Gigch [1991] allocates two main ways to build systems: improvement and design:

- An improvement process means a transformation or change that brings the system closer to standard, or normal, operating conditions. The concept of system improvement implies that the system is already created and the order of its operation is established... Analysis, analytical method (method of improvement) — a method of research, which consists in splitting the whole into parts and their separate study.
- A design process also involves transformation and change, but it is so different from the improvement process of the systems that it is necessary to emphasize the differences between them in terms of purpose, scale, methodology, ethics and results. Design is a creative process that questions the prerequisites underlying the old forms... The system approach is a principle of study that considers the system as a whole, rather than its individual subsystems. Designing the system as a whole means creating the optimal configuration (structure) of the system.

We have made these statements from general systems theory to apply them to the situation in cartography. Namely, theoretical cartography has been researching the object or system of the map for many decades. Since the 1950s, the crises of cartography have been observed every 20 years: in the 1970s, 1990s, and 2010s. At the same time, cartographers sought to overcome the crisis through improvement. And only A. Aslanikashvili for the first time clearly and reasonably proposed to change the research subject of cartography and to apply not only the analytical method but also the system method in the above sense in research.

For further explanation of this thought in fig. 2 we used the main theoretical construction of the monograph [*van Gigch*, 1991] in the context of systems design with the help of the three

[1] after 2006

inquired systems, their respective levels and the relations between the elements of these systems/levels. The levels were called: 1 — intervention, 2 — object, 3 — meta. The notion of van Gigch levels is in line with our notion of strata, so the term “stratum” is used instead of the term “level”. There are stable and repetitive relations between levels/strata, which are crucial for many areas of human activity (fig. 3).

J. van Gigch [1991, p. 256] states that exists a dialectical relation between the two elements of each dyad (object stratum ↨ metastratum, model ↨ metamodel, world ↨ metaworld, etc.), because each element is said to originate in inquiring systems of different strata of abstraction or logic. When we neglect the metastratum, we also overlook the design process that takes place at the metastratum and by which lower stratum inquiring systems are formulated. This neglect can lead to dysfunctions and to system failures.

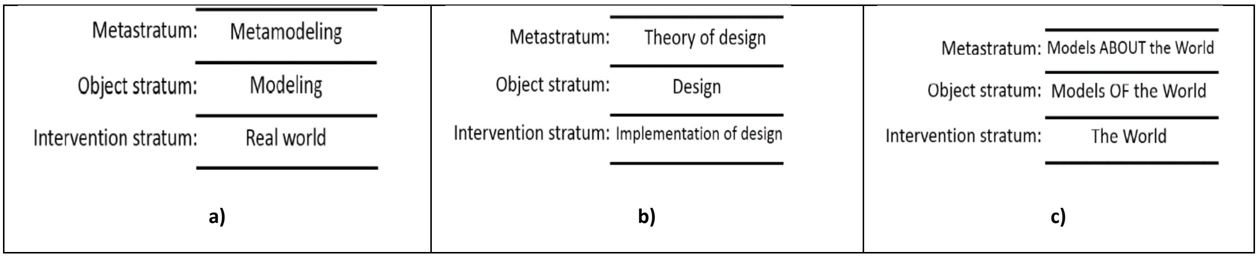

Fig. 3. The relations between:
a) modeling and metamodeling, b) design and design theory, c) cognition and metacognition

In the monograph [*Aslanikashvili*, 1974], apart from the “Introduction”, there are two chapters: “Language of map” and “Cartographic method”. That is, the theoretical construction of “Language of map” is one of the two most important elements of Metacartography. A. Aslanikashvili argued that not only the real world phenomenon (Intervention stratum) and maps (Object stratum), which could[1] represent (communicative paradigm), model (analytical paradigm), or “imitate” (critical paradigm) the real world, should be the research subject of cartography. A. Aslanikashvili quite clearly drifted the language of map to the Metastratum in the understanding of van Gigch and in our understanding. So, the notion of an ideal map was introduced, which was defined as the relation of the mutual placement of the spatial system of reference and the signs localized at a point, line, and area indicating the investigated entities of actuality (at the moment or time interval). The symbolic expression of an ideal map was understood as its logical model, that is, the model of the model by which further research was performed [*Aslanikashvili*, 1974, p. 40]. In particular, the syntax, semantics, sigmatics, and pragmatics of the language of map were explored. A. Aslanikashvili considered the cartographic method not as a method of making maps, but rather as a relation between the elements of Object stratum and Metastratum. In fact, it is precisely because of the introduction of de facto Metastratum that A. Aslanikashvili’s theoretical construction is called metacartography[2].

J. van Gigch [1991, p. 257] states that the imperative of the metasystem paradigm is to study of each object stratum system from the metastatum viewpoint. To apply this imperative is to metamodel. It is not sufficient to model; we must metamodel, that is, we must complement the formulation of models with an inquiry which raises the stratum of logic and of abstraction. By doing so, we consider the origin and underpinning of our modeling and formulate justifications for its scientific claims. Failures in modeling (and of the disciplines which adhere to the traditional

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[1] Further our clarification. In the original it was absent
[2] A. Aslanikashvili [1974] does not give a definition of metacartography

forms of modeling) can be attributed to the inadequacy of their epistemological inquiry. To question the epistemology of design is to question the prevailing paradigm. As is shown in fig. 3b, designing and questioning the design process takes place at inquiring systems of high startum of abstraction.

In figures similar to fig. 2, three similar terms are often used, which accordingly have different meanings: a system in the broader (extended) sense Sb (or SpISb), a system of SpIS (or SSpIS) systems, and a CoFr of the system under study S (CoFr S). The system Sb is used when little is known about the elements of strata higher than the Operational. In this case, the elements of the Operational stratum include SpISn. The structure of modern cartographic phenomena, such as the Google Maps Platform and the SpIS created with them, is also described by the content of the green rectangle, but in this case it is worth talking about a system of spatial systems, where elements of each stratum are spatial systems SpIS. Such are, for example, modern electronic national atlases [*Köbben,* 2013]. Finally, we will get the third content of the green rectangle if we have models of all components of the system of SpIS. However, the structure of all the examples of the systems corresponds to the structure of CoFr. In other words, all modern Cartographic information systems (CIS) have a CoFr structure, even if the developer does not know it.

It is easy to notice that the variant of system in the broader sense Sb is easily applied to the system of activities for the creation of such information product as a map. It is enough to replace the term “system” with (information) “object” or to call the map a system of map. In the first case, OMG’s Meta Object Facility can be better understood (MOF, accessed 2019–oct–15, https://www.omg.org/mof/). The second variant will become clearer from the following clarification fig. 2 for Atlas systems (AtS = EA + AtIS).

In [*Chabaniuk*, 2018, Chapter 1] on the example of the Electronic version of the National Atlas of Ukraine (ElNAU2007) it is shown that AtSn — ElNAU2007 on DVD — has a certain Atlas infrastructure. The Atlas infrastructure distinguishes two practical hierarchical strata: Application (α) and Conceptual (β). There is a theoretical General stratum (γ) “over” the Conceptual stratum (ie, “over” the Atlas infrastructure). There is a stable and repetitive relations between the elements of the neighboring strata in all known situations. AtSn refer to the Operational stratum (ω). The listed strata are hierarchically ordered: the lower is the Operational stratum, the upper one is the General stratum. Higher strata are decisive for the lower ones, so the prefix “over” is used. Taking into account Datologics, Infologics and Usagelogics, the obtained theoretical and practical constructions can be shown as in fig. 4. It is taken into account that the same construction is valid for ElNAU2000 on CD. Therefore, in fig. 4 a record is used, which refers here to two examples of AtSn: ElNAU2000 and ElNAU2007 — Operational atlas systems ωAtS.

With the above strata agreed certain phases of AtS creation, which are correlated with several structures in computer science. For example, [*Ambler*, 1998] defines four typical phases of development: Initiate, Construct, Deliver, Maintenance and Support. The Initiation phase is correlated with the AtS Research phase. Research phase artifacts (βAtS) belong to the Conceptual stratum. The Construct and Deliver phases are correlated with the AtS Development phase. The Development phase artifacts (αAtS) belong to the Application stratum. The AtS Operational phase (ωAtS) includes the Maintenance and Support phase [ibid.].

The experience of implementation of different AtSn (in particular, the above examples of ElNAU2000/2007) suggests that the hierarchy of creation phases of a particular atlas is valid also for the creation of individual maps of this atlas. These are the stages of creation performed by the developers of both software and information software ElNAU2000/2007. We hope that this example is proof of the validity of replacing the S system with a map. Thus, it was proved that RelCa is applicable not only to CIS, but also to the system of activity for making (electronic) maps.

We draw the attention of the reader to the lower and right side of Fig. 4. These are the constructions of monograph [*Klir*, 1985] that we have used to model atlas general systems. As an example, let us take the so-called general systems model of atlases base maps (GSM ABM) described in [*Chabaniuk*, *Dyshlyk*, 2016], where the mentioned general-system structures are detailed. For the purposes of this paper, it should be noted that in the actuality the entity system **O** (shown in the bottom left in fig. 4) is given, which is an element of the sourse system **S**, shown in the lower part of Fig. 4. The following formulas are valid (for the example of GSM ABM):

O=({a_i, A_i) | i={1,…,11}}, {(b_j, B_j) | j={1,2,3}}**)** — entity system, where a_i — property (entity) and A_i — set of its appearances, b_j — backdrop and B_j — set of its elements;

S=(**O**, **Ị**, **I**, ***O***, ***E***) — source system, also called the data description language [Klir, 1985; p. 16].

Ị is the specific representational system we obtain from the entity system **O** through the ***O*** observation channel. **I** is the generic representational system that we obtain from the abstraction channel ***E***. Note that in order to obtain practically useful models, you need to make observations and get a data system ^{S}**D**=(**S**, d), where d is a data function that acts on generalized mappings of backdrops and properties (entities). Conditional notation ші *d*: ***E***(***O***(**B**))→***E***(***O***(**A**)), **A**=(A_1, …, A_{11}), **B**=(B_1, B_2, B_3).

^{S}**D** is used to obtain higher strata systems. Klir [1985] calls the vertical relations between the systems thus obtained epistemological. It is fairly easy to see that hierarchically higher systems contain more knowledge about modeled actuality. Therefore, we call the “vertical” (⇅) RelCa relations by epistemology (up ↑) and reduction (down ↓). Again, it is easy to see the analogy with the results of A. Aslanikashvili. Thus, the particular space $R_{S(t)}$(S_{sis}, e_1, e_2, e_3, …, e_n) actually coincides with the entity system **O**, since, for example, in [Chabaniuk, Dyshlyk, 2016] backdrop b_1 was time, and $b_{2,3}$ — the surface of the studied territory. That is, the analogies to S_{sis} are obvious.

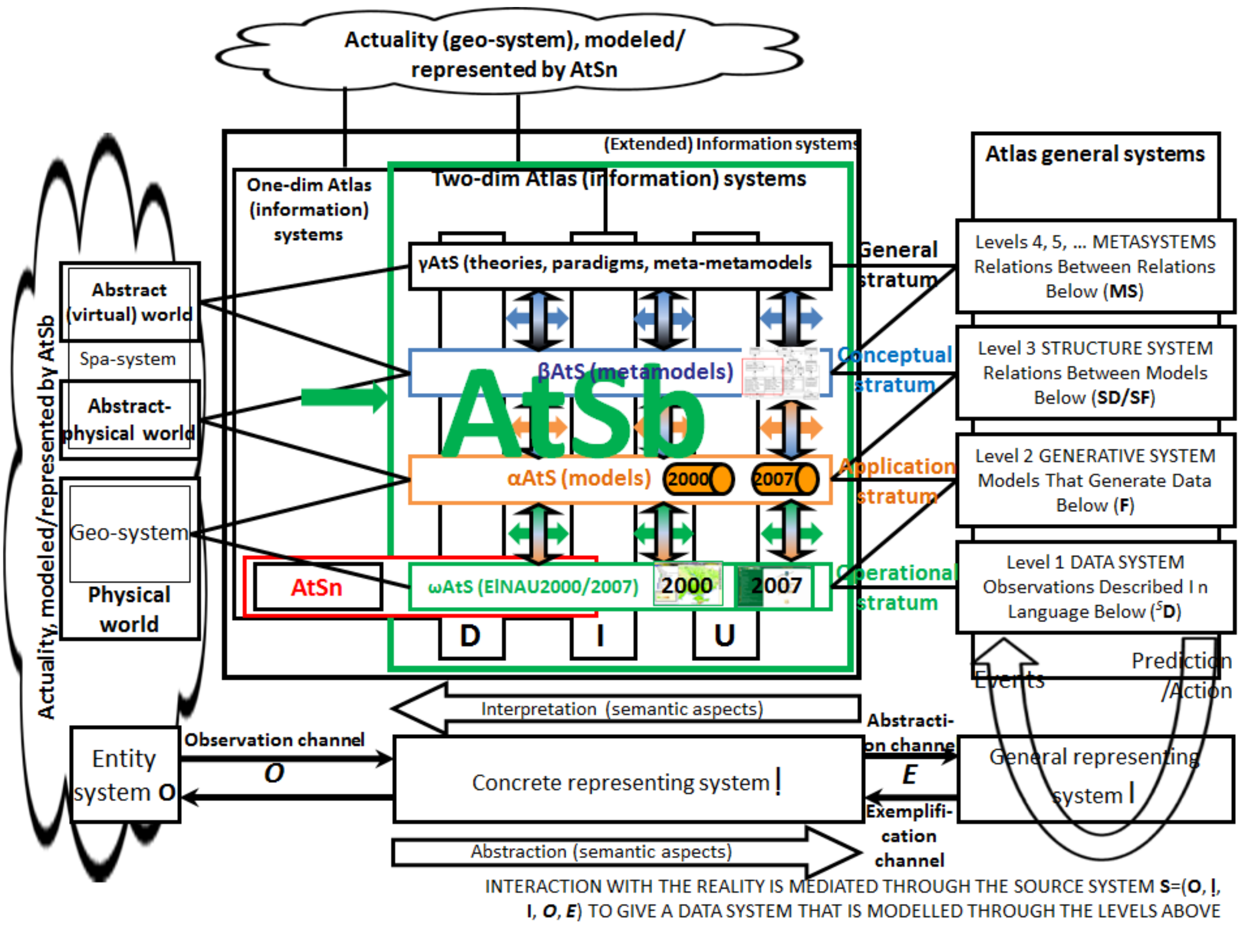

Fig. 4. Two-dimensional AtSb

We believe that the information provided is sufficient to substantiate the conclusion about the decisive impact of Metacartography on RelCa in the knowledge component about the research subject. We believe that this is an influence on the knowledge about the modeled actuality using maps and cartographic systems. More specifically, it is an influence on the knowledge of RelCa epistemological relations. As we can see, when constructing the epistemological relations of RelCa, it is possible to use a General Systems Theory. It is also possible to use Model Based Engineering [*Brambilla et al.*, 2017]. However, in both cases, you need to use map specificity. At this stage of cartography development, Metacartography is still most useful to us in this matter.

Analogies of cartographic methods of Relca and Metacartography

The RelCa methodology consists of methods: general, pattern-based, and specialized [*Chabanyuk*, 2018, Chapter 10]. RelCa specialized methods are used to find knowledge mainly about epistemological and transformational relations in cartographic systems and between cartographic systems. They are called specialized because they come from separate disciplines: cartography, computer science and systemology. The specialized methods of cartography are almost entirely based on A. Aslanikashvili's cartographic method.

Recall the cartographic method of cognition, which is described in detail in the monograph [*Aslanikashvili*, 1974] and is briefly presented in fig. 5 with some changes.

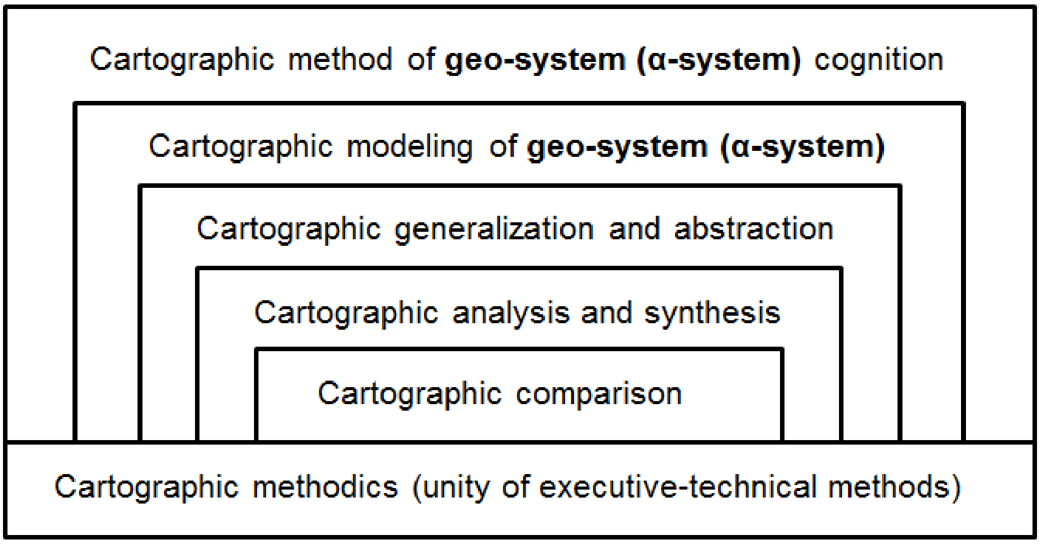

Fig. 5. A hierarchy of cartographic forms of research of the "cartographic method of cognition of 'geo-systems'" [Aslanikashvili, 1974, p. 120]

The changes to fig. 5 in comparison with the original figure is the addition of the boldface font phrase **"geo-system (α-system)"** to the sentences "Cartographic method of… cognition" and "Cartographic modeling of…". The reason for these changes in terms of notation is explained by fig. 6, which is made from CoFr AtS.

Recall that RelCa researches the relations in geo-systems (or α-systems) that are defined (exist) in the physical world, as well as in two kinds of spa-systems, which are referred here as β- and γ-systems. β-systems are given (exist) in the so-called abstract-physical world, and γ-systems — in the abstract (or purely virtual) world.

Aslanikashvili [1974] did not distinguish the abovementioned physical, abstract—physical and abstract worlds in the actuality modeled by maps. Therefore, we can assume that A. Aslanikashvili mapping forms of research can have "subforms" in each of the three worlds. Consider, for example, cartographic modeling, which according to [*Aslanikashvili*, 1974] includes all other forms of cartographic research.

J. van Gigch [1991] proved that if it is possible to model, then it is possible, and even necessary, to metamodel. Let us take this view by executing the above: if metamodeling is possible, then meta-metamodeling is possible. Continuing these conclusions, we can prove that if there is cartographic modeling, then there must be both cartographic metamodeling and cartographic meta-metamodeling. Moreover, cartographic metamodeling is not only possible but even necessary if it is not the modeled individual maps but the cartographic systems. In support of this view, the monograph [*Chabaniuk*, 2018] provides some examples of related cartographic models (α-models) and metamodels (β-models).

CONCLUSIONS

It is proved in the work, that Metacartography has a significant impact on the three major components of RelCa [*Chabaniuk*, 2018] as a science:

1. The research subjects (inquiry domains) of the two paradigms of cartography practically coincide. In Metacartography this is a concrete space of modeled actuality. In RelCa this is a relational space and modeling them geo- and spatial systems. If we consider only analog models of actuality (in particular, paper maps), the coincidence will be complete. When considering modern electronic models of actuality, a concrete space of Metacartography is included in the relational spaces of RelCa.
2. The most useful impact of Metacartography on the knowledge of the RelCa research subject is knowledge of the presence and cartographic specificity of recurrent epistemological relations in and between cartographic systems.
3. RelCa specialized cartographic methods are based on the Cartographic method of Metacartography.

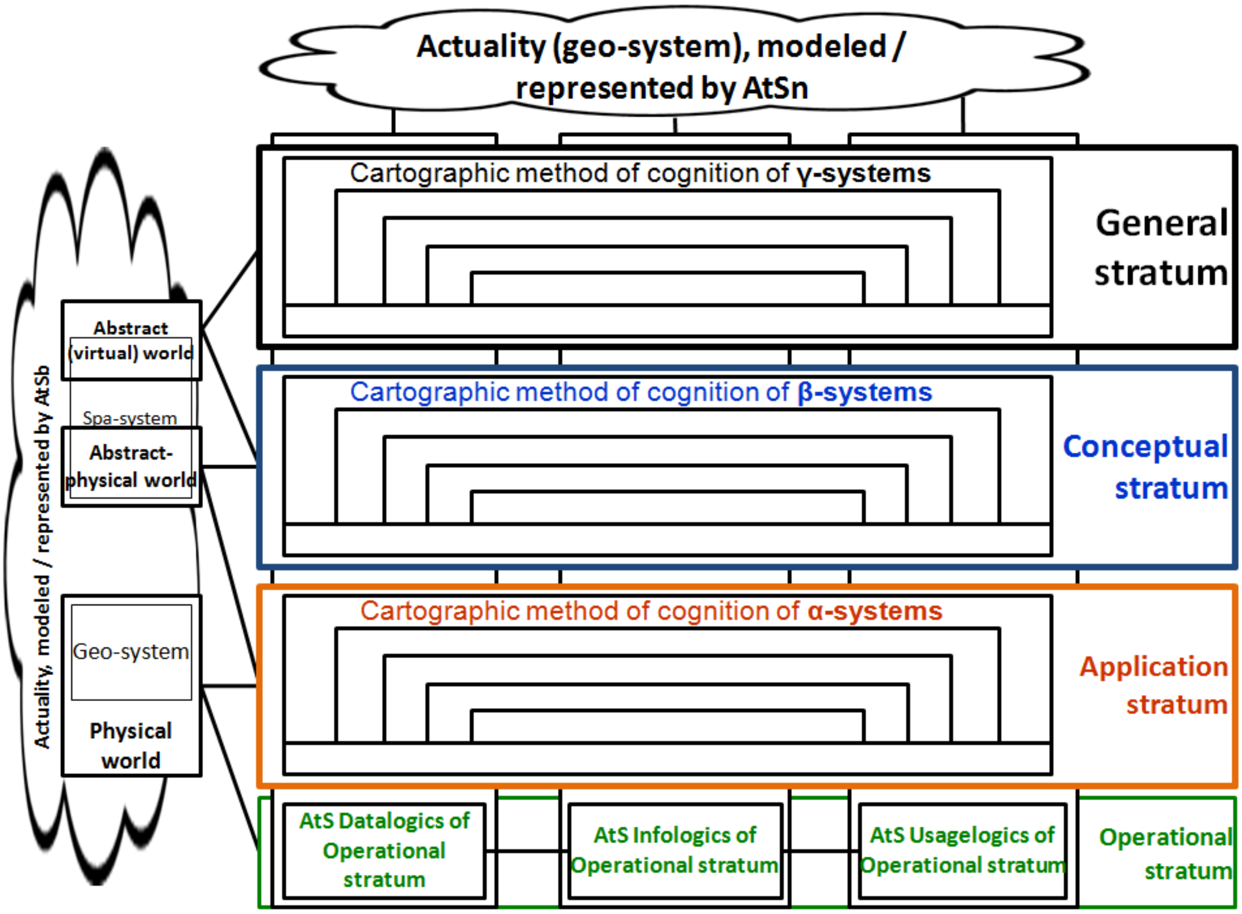

Fig. 6. Cartographic method of cognition of α-, β- and γ-systems

Finally, we note that in the last century, J. Berten, A. Aslanikashvili, L. Rataysky, A. Liuty, and other scholars laid the fundamental foundations of the concept of the language of map. Unfortunately, the absence of English-language publications by A. Aslanikashvili and A. Liuty, according to our data, did not contribute to their widespread distribution and, accordingly, to the international society of cartographers and geographers. At the same time, in the post-Soviet space, cartography did not perceive the objective vision of the language of map and did not fully acknowledge in it the basic essence, which is largely due to its appearance and evolution.

There were many reasons for this. For example, in the monograph [*Rudenko,* 1984, p. 50] the following definition of geosystem was used [*Aslanikashvili,* 1978, p. 155]: "The geosystem is a globally organized dynamic system of managing the processes of spatial relations of innumerable relations of energy, matter and information exchange between material bodies and phenomena in the Earth's landscape shell at the noospheric level of its evolution." To this definition was added: "... a dynamic system of certain conditions and objects, as well as a system...". Such an understanding was followed by L. Rudenko in his monograph, where the principles of territorial planning were actually developed by means of an "analog" cartographic system.

However, later, in the project of the conception development of the National GIS (NGIS) of Ukraine [*Rudenko, Chabanyuk,* 1994], in the conditions of collapse of the Soviet Union, it was declared impossible to create the NGIS. Instead, it was proposed to create conditions for the development of NGIS class systems, which could include cartographic systems of the class actually described in [*Rudenko,* 1984]. To use modern terminology, it was proposed to create a National Spatial Data Infrastructure (NSDI) instead of the NGIS. In practice, the National Atlas of Ukraine was later created [*Rudenko et al.,* 2007], which utilized practically implementible at that time cartographic and geographic achievements.

Of course, our experience cannot be an objective explanation for the limited use of cartographic paradigms by A. Aslanikashvili and A. Liuty. Their detailed consideration needs special attention. But recall the words of A. Liuty, which he wrote at the conclusion of his doctoral dissertation in 1989: "The main results of the dissertation are the discovery of regularity of the structure and functioning of the language of map as an object phenomenon, the development of the foundations of its theory, practical grammar and the development on this basis of a new language-semiotic approach to understanding cartographic science and the corresponding conception-hypothesis, integrating previously proposed scientific schemes, expanding and deepening research program taking into account the achievements of scientific and technological progress."

It is obvious that all cartographers and geographers should return to the results of A. Aslanikashvili and A. Liuty to work on the next steps in the development of cartography theory. It seems to us that the time has come and there are opportunities for a full understanding of the results of these scientists. And Relational Cartography is the first step in this direction.

REFERENCES

1. *Ambler S.* An introduction to process patterns. AmbySoft Inc. White Paper, 1998. 18 p.
2. *Aslanikashvili A.F.* Cartography. The general theory questions. Tbilisi: Metsniereba, 1968. 299 p. (in Georgian).
3. *Aslanikashvili A.F.* Metacartography. Main problems. Tbilisi: Metsniereba, 1974. 126 p. (in Russian).
4. *Aslanikashvili A.F.* Object and theoretical basis to use cartographic method in geographic research. Proceedings of the Geographical Society of the Georgian SSR, 1973. V. 12 (in Russian).
5. *Aslanikashvili A.F.* The cognition subject of geography. Proceedings of the USSR Academy of Sciences. Geographical Series, 1978. No 2. P. 150−156 (in Russian).
6. *Azócar Fernandez P.I., Buchroithner M.F.* Paradigms in cartography: An epistemological review of the 20th and 21st centuries. Springer, 2014. 150 p.
7. *Berlyant A.M.* Geoiconics. Moscow: Astrea, 1996. 208 p. (in Russian).
8. *Berlyant A.M.* Theory of geoimages. Moscow: GEOS, 2006. 262 p. (in Russian).

9. *Brambilla M., Cabot J., Wimmer M*. Model-driven software engineering in practice. Morgan & Claypool Publishers, 2nd ed., 2017. 209 p.
10. *Bunge W*. Theoretical geography: translation from English. Moscow: Progress, 1967. 279 p. (in Russian).
11. *Cauvin C., Escobar F., Serradj A*. Thematic cartography. V. 1: Thematic cartography and transformations. ISTE-Wiley, 2010. 512 p.
12. *Chabaniuk V*. Relational cartography: theory and practice. Kiev: Institute of Geography of the NAS of Ukraine, 2018. 525 p. (in Ukrainian).
13. *Chabaniuk V., Dyshlyk O*. Atlas basemaps in web 2.0 Epoch. The international archives of the photogrammetry, remote sensing and spatial information sciences. XXIII ISPRS Congress 12–19 July 2016. Prague, Czech Republic, 2016. V. XLI–B4. P. 611–618.
14. *Chabaniuk V., Rudenko L*. Relational geospatial technologies: Background theory, practical example and needs in education, in geospatial technologies in geography education. Geospatial Technologies in Geography Education. Springer, 2019. P. 63-83.
15. *Cresswell T*. Geographic thought: A critical introduction (Critical introductions to geography). Wiley−Blackwell, 2013. 298 p.
16. *Falkenberg E.D., Lindgreen P*. Information system concepts: An in-depth analysis. Amsterdam: North-Holland, 1989. 357 p.
17. *Holyoak K.J., Morrison R.G*. The Oxford Handbook of Thinking and Reasoning. Oxford University Press, 2012. 865 p.
18. *Klir G.J*. Architecture of systems problem solving. Springer, 1985. 560 p.
19. *Köbben B*. Towards a national atlas of the Netherlands as part of the national spatial data Infrastructure. The Cartographic Journal, 2013. V. 50. No 3. P. 225–231.
20. *Liuty A.A*. Language of map. Moscow: Znanie, 1981. 48 p. (in Russian).
21. *Liuty A.A*. Language of map: essence, system, functions. Moscow: IG, USSR AS, 1988. 292 p. (in Russian).
22. *Liuty A.A*. Language of map: essence, system, functions. Abstract of diss… Doctor of geogr. sc. Kiev, 1989 (in Russian).
23. *Lurie I.K*. Geoinformation cartography. Methods of geoinformatics and digital processing of satellite images: A textbook. Moscow: KDU, 2008. 424 p. (in Russian).
24. *Lyashenko D., Kozachenko T*. The concept of geoinformation cartography and its evolution. Geoinformation cartography in Ukraine: Conceptual background and directions of evolution. Kiev: Naukova dumka, 2011. P. 15−54 (in Ukrainian).
25. *Miller H.J*. The data avalanche is here. Shouldn't we be digging? Journal of Regional Science, 2010. V. 50. No 1. P. 181−201.
26. *Roth R.E*. Interacting with Maps: The science and practice of cartographic interaction. Diss… Doctor of philos. (geogr.) sc. The Pennsylvania State University, 2011. 225 p.
27. *Rudenko L.G*. Cartographic substantiation of territorial planning. Kiev: Naukova Dumka, 1984. 168 p. (in Russian).
28. *Rudenko L.G., Bochkovska A.I., Kozachenko T.I., Parchomenko G.O., Razov V.P., Lyashenko D.O., Chabaniuk V.S.* National atlas of Ukraine. Scientific backgrounds of creation and their realization. Kiev: Academperiodics, 2007. 408 p. (in Ukrainian).
29. *Rudenko L.G., Chabaniuk V.S*. Foundations of the conception of the multipurpose GIS of Ukraine. Ukrainian Geographical Journal, 1994. No 3. P. 22–34 (in Ukrainain).
30. *Sieber R., Hollenstein L., Odden B., Hurni L*. From classic atlas design to collaborative platforms — The SwissAtlasPlatform Project. 25th International cartographic conference. Paris, 2011. 10 p.
31. *Sui D., Holt J*. Visualizing and analyzing public-health data using value-by-area cartograms: Toward a new synthetic framework. Cartographica, 2008. V. 43. Iss. 1. P. 3–20.
32. *Van Gigch J.P*. System design modeling and metamodeling. Springer, 1991. 453 p.