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Combinational Analysis of Architectural Shaping Based on Crystal Lattice of Minerals

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Abstract: This article describes a new scientific field called architectural geonics, covering issues related to the combinational analysis of architectural shaping based on crystal lattice of minerals. Authors give examples of the crystalline structures of some minerals and their use in the design of architectural objects. Article addresses also the issues on interrelationship between geomorphologic characteristics of the territory in the context of the Belgorod region and architectural and space-planning design of architectural objects.

Key words: Architecture · Architectural geonics · Crystals · Crystal lattice · Shaping

INTRODUCTION

Curious mind of humanity never rests. Development of scientific and technological progress results in the conflict between a human's intention to protect nature and to take advantage of it. Urbanized environment often becomes uncomfortable and sometimes hostile to human. Searching a balance between natural and artificial components of the living environment and environmental protection leads to emergence of contemporary innovative interdisciplinary research areas, such as, for example, architectural geonics. It is a scientific field that uses the analysis of the structures and processes occurring in the inorganic world when solving up-to-date engineering problems [1-4].

Throughout the mankind development, architecture always met the requirements of stiffness, functionality and aesthetics. With the emergence of new materials and construction equipment this triad has not lost its relevance [5-11]. In seismically unstable areas, a high strength of architectural structures is a matter of life and death. In inanimate nature one of the most static objects are inorganic minerals. Study of minerals offers a great variety of various crystal lattices structures having different stiffness. These findings cannot be overlooked by architects and urban planners. In fact, all structures, both biological and inorganic (as well as urban facilities), are hierarchical. Today, scientists argue that the answer to the question: "Does the paulingite have genes?" is definitely positive. This is the first step in solving the problem of inorganic substances self-organization [12].

At the end of the XX century the natural sciences experienced certain changing. The mathematical theory of self-organization was considered to be thoroughly developed. It allowed scientists to make a fresh look at the world and undermined unambiguous determinism [13]. This theory served a basis for a new interdisciplinary field of science namely synergetics, which was "engaged in the study of processes of self-organization and emergence, maintenance, sustainability and the breakdown of various nature structures" [14]. Considerable attention was paid to the fractal theory. Architects and urban planners began to use this concept in their creativity. The concept of creating analytical models of cities and urban environment regions using fractal theory demonstrated in general the wide range of applications of this theory in urban planning and architecture, as well as the development of the promising methods of modeling urban facilities [15]. The main properties of fractal structures in architecture and urban planning can be attributed to the self-similarity or hierarchical pattern (multi-layer structure), the potency for development and continuous movement (genetic pattern), fractional dimensionality, continuity and appurtenance in equal measure to chaos and order. The projects based on use of fractal theory, such as works of P. Eisenman and Ch. Jencks, as well as the general plan of the Dubai city (UAE), were created and implemented in architecture and urban planning [16].

Computer science merges with structure. Spatial definition of space and information measure is incorporated in the formal mathematical apparatus of geometry and possibly must conform to their definitions

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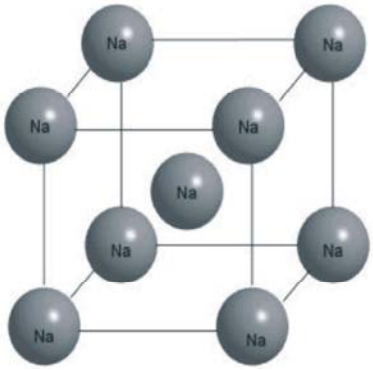

Fig. 1: Crystal lattice of sodium.

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Fig. 2: Structure of the diamond lattice.

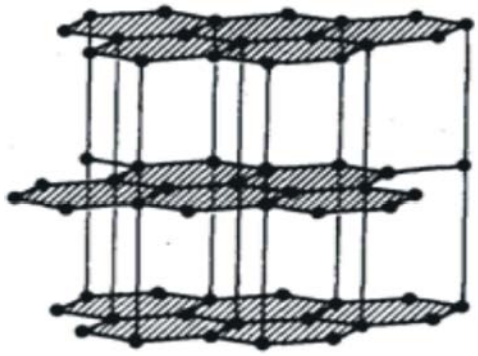

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Fig. 3: Structure of the graphite lattice.

in other areas of science (the same way as definition of measure constitutes axiomatic basis of generalized crystallography according to McKay). Crystallographic structure is characterized by regular (ordered) arrangement of particles in certain places in the crystal. When connecting these points imaginatively by lines, we obtain spatial frame, which is called a crystal lattice. It should be noted that crystals are likely abnormality, because they are formed from a single atom to the molecular structure based on a same rule (this is the rule of translational invariance) [12]. In architecture, the crystal lattice can serve as an accessory geometrical image, introduced for analyzing the object structure. The grid is similar to the canvas or mesh, kind of architectural (or constructional) module. Perfect crystal lattice is a repetition of elementary crystal cells. Consider several types of crystal lattices. In the metal crystal of sodium (Fig. 1) each sodium ion is surrounded by eight nearest neighbors; it is particularly well illustrated by the atom, which is placed in the center of the cube. But all the atoms in the metal sodium are equivalent and have the same neighborhood. Thus, the coordination number of the sodium in the metal crystal is equal to 8. If we continue drawing the crystal lattice, we will reveal that it is composed of repeating structural units or "elements". Such structural unit is called the unit cell.

In terms of crystallographic features, the most important for architects is just a spatial periodicity in the arrangement of particles (particles are considered as geometric points). Crystal lattice can have various types of symmetry. Symmetry of the crystal lattice is its property to coincide with itself at a certain spatial movements, such as parallel translations, rotations, reflections, or combinations thereof, etc. In atomic crystals, which are, for example, diamond and graphite (two different states of carbon), the lattice structure is such that each carbon atom is surrounded by four similar atoms, located in the vertices of the tetrahedron at equal distances from this atom (Fig. 2). Some solids may simultaneously have several kinds of interatomic bonds. Graphite (a hexagonal lattice) may serve as a good example. Graphite grid (Fig. 3) consists of a number of parallel planes, in which the carbon atoms are located at the vertices of regular hexagons.

Basis of the diamond structure (the geometry of its crystal lattice) consists of centered tetrahedrons that serve as elementary and spatial cells of rigidity and strength. Particles of substance in diamond are distributed equally firmly and evenly, providing the highest hardness and strength. When considering a separate tetrahedron, one can assume it as a module, because it is a unified standard element or combinatorial uniform component. As is obvious, crystal lattice structures display combinatorial pattern.

According to the architectural combinatorial theory (one of the architectural theory fields, which studies the shaping issues based on various combinations), several simplest types of elements (like modules) can generate a new, more complex modular systems, allowing one to

expand and enrich the capabilities of shaping [17]. Combinatorial theory of architectural shaping based on crystal lattices of minerals will allow one to create a variety of modular structures with an exciting non-standard architecture. When creating modules, one should take into account the geological environment, which would serve a ground for erecting buildings. Study of the structural features, shaping and growth of minerals crystalline structures will allow a deeper understanding of the nature and sustainability of the environment, as well as make it possible to find the most correct space-planning solution for the designed facility.

The practice of mass residential development and industrial construction without relationship of housing forms with local peculiarities of natural environment (especially with regard to terrain conformation and vegetation) has led to disruption of harmony between the architectural structures and human needs, whereas multistory buildings do not provide the necessary interrelation with the adjacent land areas. A particular problem, such as a progressive decline in the aesthetic qualities of suburban and urban areas, should be highlighted particularly. Very often we can see a faceless urban developments, where ignoring the laws of composition, coloristic and rhythm result in emergence of boring unifor m high-rise buildings, uncomfortable for living. At that, the elimination of normal yard spaces creates an uncomfortable environment not only for its functional qualities, but also for the negative impact on the human nervous system. Loss by natural landscapes ability to self-regulate when transforming into anthropogenic environments led to a situation where many of the cities have approached the beginning of the third millennium with profound problems related to ensuring proper conditions for human life. Society has faced not only with impaired ecological uniqueness of the natural environment, but also with serious medical problems, such as depression, chronic fatigue, nervous overload and stress that cannot be overcome just by medicinal treatment [18].

It is imperative to find a way how to maintain a balance between natural and artificial components of environment, ensuring its ecological sustainability under conditions of radically altered natural landscape and the increasing impact of anthropogenic factors. The experience of many countries shows that the choice of approaches to transform the environment is determined by the balancing rate of its constituent natural, artificial and anthropogenic elements. It is their balanced development or disequilibrium that contains prerequisites of the existence of anthropogenic landscape, or the accumulation of tension with the aggravation of environmental problems. The stronger is the alienation of a human from the original natural landscape, the more strong is his intention to fill the resulting emotional "vacuum" owing to a new look at design. He tries to bring "pieces of nature" back to the urban environment. Therefore special attention is being given to the formation in urban environment of green spaces, creation of various pedestrian zones, etc.

In this connection, it is necessary to create an environment that would have a positive effect on the human body; and here architectural geonics, being one of the particular areas of geonics, can help to solve the problem. Geonics is a science that deals with the engineering problems solution, based on the knowledge gained in the study of geological and cosmochemical processes [19]. Major areas of geonics, being considered at the moment, are related to the optimization of the system "human-material-ecosystem", including the development and adaptation of underground space, the problems of organic and inorganic world development (existence), the design of algorithms and models for creation and management of the objects of inorganic world, use of energy from geological and cosmic processes, as well as process development for production of minerals and composites.

By analogy with the architectural bionics, a term that has long become of common use and does not surprise anyone, we may assume that architectural geonics may become another promising research area that will ensure the creation of architectural ensembles reflecting the impact of geological and cosmochemical processes on inorganic world [19].

Even now, when constructing modern architectural objects, designers follow challenging idea to create a comfortable environment for a human living, based on the elements of architectural-geonics model. For example, an architectural company Bebin & Saxton constructed Aonni Mineral Water plant. The building consists of a variety of structural units that create certain harmony with the local landscape. The architects had to execute the project with all the environmental regulations of the area. The project provides maximum use of natural light that resulted in reduction of energy consumption and operating costs. The whole structure can be recycled and re-used that guarantees a long life cycle of all materials. It is natural that the water itself served an image of the project design. Since the water may exist in three physical states including ice, the plant complex resembles ice crystals (Fig. 4).

Fig. 4: Aonni Mineral Water plant resembles ice crystals.

Fig. 5: The similarity of a crystal with the private house, designed by D. Libeskind.

In 2010, Daniel Libeskind designed and implemented a small-area private country house, sheltered from prying eyes, with the intriguing name "18.36.54" [20]. At first glance the house looks too low and cramped for an adult, too closed, too urban and dynamic for country landscape. But if one looks closely and feels the project plastics, all these illusions are scattered. Emphatic geometric character of the building of 186 square meters is shaped by connecting surfaces at different angles. In total it has 18 faces, 36 edges and 54 vertices. This explains the origin of the house name "18.36.54". It is quite hard to characterize the resulting structure, because its shape changes depending on the foreshortening. But most of all it reminds kind of crystal that was undergone deconstruction (Fig. 5).

According to the authors of the present paper, designing public or residential architectural objects requires not only analysis of topographical relief but investigation of geology of the territory, where the object will be situated, as well as the study of structural features of outcropping minerals and their clusters. The structure (frame, location and order) of a substance is a fundamental characteristic of any matter; it is a set of sustainable object relationships that provides its integrity and identity to itself, i.e. preservation of the basic properties at various internal and external dimensions [12]. This definition introduces geometry to the world of structural chemistry as definition of space measure.

Analyzing the structure of inanimate nature objects, architects have the opportunity to trace self-organization of these objects in a particular space and apply the "experience" when designing the local urban and architectural sites.

Considering the natural landscapes of the Belgorod region, we should note its rich chalkstone deposits. The most extensive and high-quality field of sedimentary rock of organic (zoogenic) origin in Russia is situated in Belgorod region. This is a historically close and "native" natural material for the residents of the region. It becomes apparent that the study of the chalkstone structure may provide a wide space for creativity of architects in the region.

When viewing chalkstone through a microscope, it becomes apparent that some chalkstone particles bristle like "hedgehogs", while others are smooth. Microstructure affects the chalkstone ductility, fluidity, operational characteristics during processing and other important properties that determine the quality of the final product.

Basically, Belgorod chalkstone has flabelliform structure. This means a greater fluidity of the chalkstone that has several advantages over the same raw material deposited in other areas.

Data from recent micropaleontological studies show that chalkstone consists of small organisms. These are coccolithales, a group of single-celled planktonic Haptophyta algae, forming on the surface limestone

Fig. 6: Landscape features of Belgorod region.

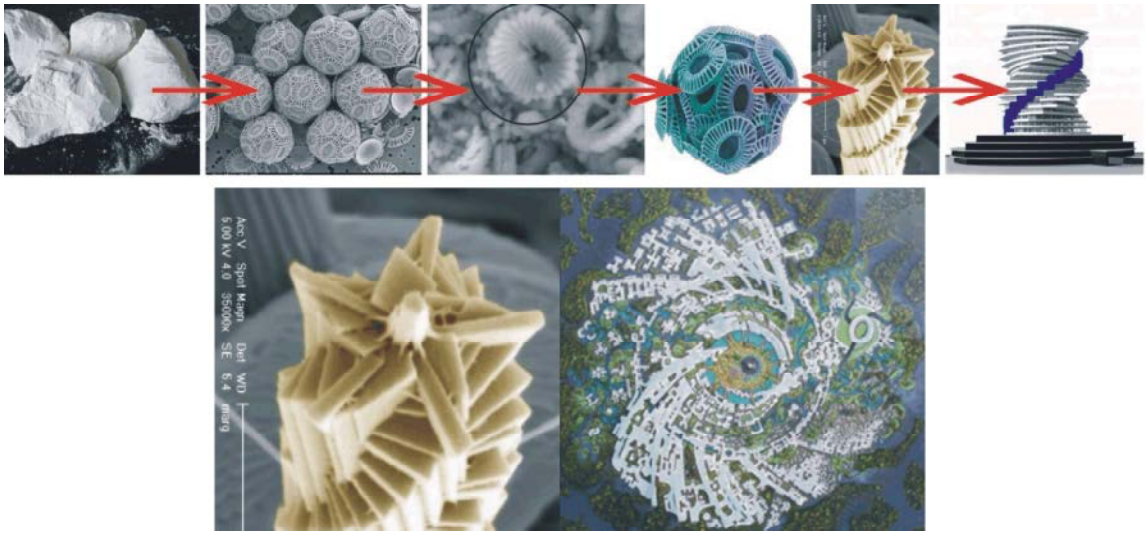

Fig. 7: Creative search for shape of architectural object, based on the chalkstone structure.

plates, so-termed, coccolites. Coccolithales constitute a significant part (98%) of nannoplankton and their calcareous skeletons, which make up the bottom sediment, are often used to determine the age of rocks [13]. The largest nannoplankton, called *Emiliania huxleyi*, is now living in the world ocean. As mentioned, they are called nannoplankton, which originates from the Greek "nanos" (dwarf) and looks through the microscope like a spiral. Discovery of fossil coccolithales is associated with the investigation of the Cretaceous deposits (commonly known in the literature as "White Cliffs of Dover"). At the end of IX century, researchers discovered the presence of tiny shells of these organisms. Facies of writing chalkstone are mainly represented by coccolithales.

Unique objects of organic and inorganic world, in terms of their beauty, color and shape, emerge as a result of geological and cosmological processes. Based on the analysis of chalkstone, we can imagine, how the architectural object would look if based on chalkstone structure and be appropriate to concerned climate and geomorphic zone (Fig. 7).

Thus, when designing the racetrack, undergraduate student girl took the scaly structure of Belgorod chalkstone as a conceptual basis for designing large-span shell of the object (Fig. 8).

Human's perception of space around himself is influenced by many factors, including vision of comfort, shape proportion and identity. Environment becomes the "sphere" for affordable and motivated visit of a human only in case of proper space structuring and availability of those elements, which are necessary for the implementation of its function and correspond to the concepts of potential consumers.

In particular, the analysis of the objectives and societal ends, conducted by A.G. Bol'shakov, "... allowed one to distinguish seven motivations of social reproduction. These include: health, wealth, commonality, beauty, individualization, information and spirituality. Each motivation is accomplished in terms of a tendency to transform a territory"[14].

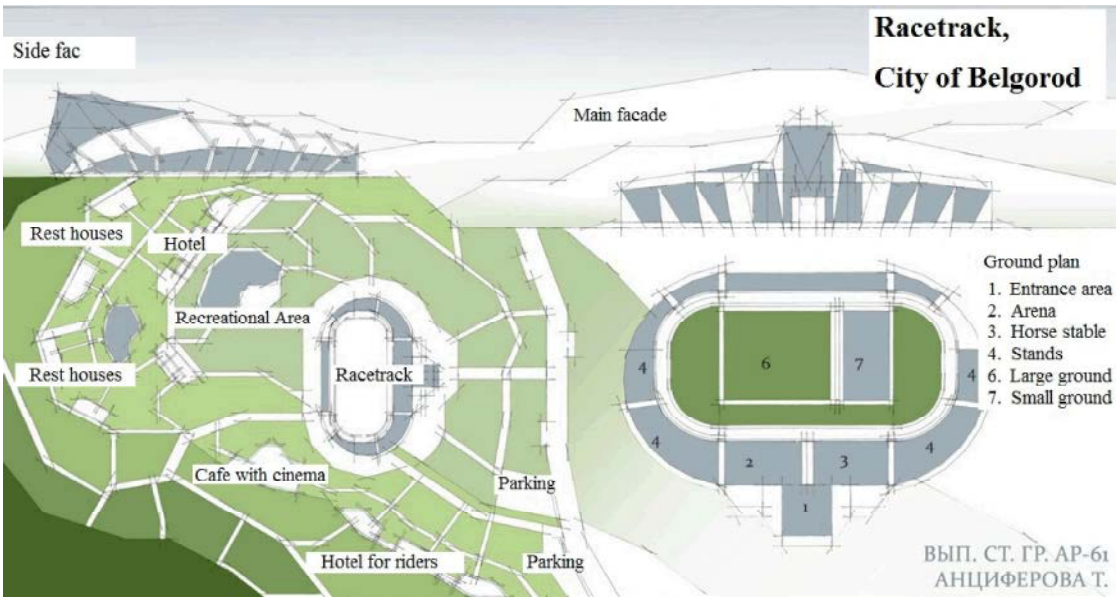

Fig. 8: Clausura designed by undergraduate student T. Antsifirova regarding the project "Racetrack in Belgorod".

Noted motivations reflect human interests primarily in ensuring his survival in a built environment, creating comfortable living conditions and forming the environment with distinctive and recognizable features of the local area.

Motivations to transform the human environment represent, to some extent, a reflection of human's current condition. With the increase of people's level of education, culture and needs, their demands for unique natural and artificial (architectural) objects increase as well. Socio-ecological motives for environmental changes become available to the extent that the "resource" attitude of society towards nature is gradually overpassed. These motives exhibit through appearing of benchmarks focused on achieving new environmental qualities.

Thus, architectural geonics allows specialists to develop new tectonics for architectural ensembles. This is based on consistent consideration of systemic approaches to the formation of the various object components and their application in relation to the space of human living environment. This will allow one to design structures that would organically fit into the living environment in accordance with the geomorphology, climate and cultural traditions. It also seems that a new scientific field not only solves the practical aspects of the living environment, creates structural elements, shapes, space, etc., but also helps to improve the human's emotional state and forms around the human a truly comfortable space.

REFERENCES

1. Lesovik, V.S., 2013. Architectural Geonics. Housing Construction, 1: 9-12.
2. Nefedov, V.A., 2012. Urban Landscaping. St-Petersburg: Lubavitch, pp: 320.
3. Pronin, E.S., 2004. Theoretical foundations of architectural combinations. Architecture, pp: 232.
4. Bozhko, Y.G., 1984. Basics of forming architectonics and combinatorial theory. Kharkov: Higher School, pp: 184.
5. Alexander, C., 1964. Notes on the Synthesis of Form. Harvard: Harvard University Press, pp: 1-327.
6. Alexander, C., 1966. A City is not a Tree. Design, pp: 32-34.
7. Alexander, C., S. Hirshen and S. Ishikawa, 1969. Coffinj. Houses generated by Patterns. Berkeley: CES, pp: 1-302.
8. Alexander, C., 1970. The Environment. Japan Architect, pp: 165.
9. Apps, P., 1976. Architectural design and the problem of evaluation. The Architecture of form, Cambridge: Cambridge University Press, pp: 41-48.
10. Bon, R., 1971. Presentation to the Morphology Group mimeograph. Department of City and Regional Planning. Harvard University, Cambridge, MA, pp: 27.
11. Canter, D., 1974. Psychology and the Built Environment. New York, pp: 27.
12. Lord, E.E., 2010. New geometry for new materials. Moscow: Fizmatlit.

13. Airapetov, A.A., 2006. Problems of application of fractal theory in architecture. Issues of architectural theory. Architectural and theoretical thought of Modern and Contemporary History, KomKniga, pp: 305-320.
14. Arshinov, V.I., 1999. Synergetics as a phenomenon of postnonclassical science. Moscow, Institute of Philosophy, Russian Academy of Sciences.
15. Kolyasnikov, V.A., 2010. Modern theory and practice of urban development: spatial planning of cities. Yekaterinburg: Architect, pp: 505.
16. Kravchenko, M.P., 2010. The development of fractal theory in architecture. Moscow.
17. Belyakova, G.A., 2006. Botany: algae and fungi. Volume 2, Academia.
18. Bolshakov, A.G., 2003. Urban planning of landscape as a factor of sustainable development of the territory, PhD thesis, Ir STU, Irkutsk.
19. Lesovik, V.S., 2012. Geonics. Subject and tasks. Belgorod: BSTU, pp: 213.
20. Daniel Libeskind. Date Views 2013 www:archi.ru/ architects/world/22/daniel-libeskind.