Mineralogical Breakthrough into Nanoworld: Results and Challenges

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Abstract. A bit more than a hundred years ago Wolfgang Ostwald, Professor at the University of Leipzig, published a book titled "The World of Neglected Dimensions" (Ostwald 1923). He announced a program of a research breakthrough into the world of microscopic particles, which was imminent by that time. A new stage of the intervention into "world of neglected dimensions" began near the end of the 20th century. The main objects at this stage were nanosized particles. The agenda raised issue of development of new sciences, including nanomineralogy. The subsequent mineralogical intervention into the "world of neglected dimensions" proved to be quite successful. We associate challenges of the next breakthrough with the study of objects and processes in the range from individual atoms and molecules to the first mineral individuals (nanoindividuals). The protomineral world is today a new "world of neglected dimensions".

Keywords: "world of neglected dimensions" · Nanoparticles · Quatarone concept · Protomineral world

1 Introduction

The unprecedented interest in nanoscale objects, which we witness in recent years, I called a new stage of intervention into the "world of neglected dimensions". The first stage of the intervention (research breakthrough) occurred at the beginning of the 20^{th} century and was associated with W. Ostwald, who actually referred to the region of microscopic particles as "the world of neglected dimensions" (Ostwald 1923). Intensive researches in this area, which began then, resulted in formation of a new science - colloid chemistry. Its creators R. Zigmondi ("he opened access to the world of inaccessible sizes"), T. Svedberg and J. Perrin (for "a breakthrough into the world of discrete particles") were awarded the Nobel Prizes in 1925 and 1926. What is happening in our time is a secondary discovery of the "world of neglected dimensions", now not only at micro, but also at nanoscale.

Mineralogical intervention into the micro and nanoworld began long ago. There is generally nothing revolutionary in what is happening nowadays. Nano-mineralogy is a normal and inevitable stage in the development of mineralogical science. Moreover the role of mineralogy (crystallography) in the study of nanoscale objects is quite comparable with the role of physics, chemistry or biology. Suffice it to recall that structural mineralogy always operated on nanoscale elements, and nucleation and growth of

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crystals is a typical nanoprocess, a crystalline nucleus is a nanocrystal, and opal is a nanostructured natural material. Nanotechnology is often a repetition of natural processes or nature-like technologies.

The very first results of the mineralogical intervention in the nanoworld were very impressive (Nanomineralogy… 2005). Among the most important achievements of the past years:

- - discovery of a new type of structurally and morphologically ordered objects – nanoindividuals. The likely morphological diversity of nanoindividuals is enormous and not limited by laws of classical crystallography;
- - significant expansion of boundaries of mineral world due to solid amorphous substances previously attributed to mineraloids. A discovery of a new class of structurally ordered mineral structures;
- - finding of the lower limit of mineral objects, beyond which matter is in a different, non-mineral (protomineral, quatarone, cluster) state;
- - identification of common laws of self-organization at nanoscale in the mineral and living worlds. Mineral and living matter, as is known, are formed at nanoscale. Both do not exist outside the lower limit of the nanolevel;
- - substantiation of fundamental role of forms of existence and properties of nanoscale particles in minerals and ores for the development of new technologies for deep and complex processing of mineral raw.

The research of the mineral nanoworld is just beginning. The study of mineral nanostructures, natural clusters, nanostructured natural materials, organo-mineral nanoobjects, nanodispersed phases in ores, development of new technologies for their extraction, modifying properties of minerals and mineral nanoparticles is an incomplete list of the nearest tasks of general and applied nanomineralogy. At that we will have to reconsider a number of fundamental concepts, significantly expand them or introduce new ones. Another argument for the expansion of mineralogical objects to nanoscale is that on this basis a great challenge for mineralogical science can be formed, which is now missing. It is not reasonable to reject a breakthrough promising unprecedented discoveries and a deeper understanding of nature of the mineral matter and its sources. It is hard to deny the intellectual appeal and charm of the nanomineralogical project. The opening door to the nanoworld should not be closed, even if there is a threat of erosion of foundations of classical mineralogy.

Significant progress in understanding properties of the nanoworld was made by the quatarone concept of cluster self-organization of matter developed by us (Askhabov 2011). Within this concept new models of crystal nucleation (Askhabov 2016), formation of various types of nanoparticles (including fullerenes (Askhabov 2005a)) and solid amorphous materials (Askhabov 2005b) are proposed. At that quatarons themselves are new nanoobjects without analogues in the macroworld. They are not small pieces, cut from a large piece of matter or obtained by successive division. They cannot be identified with ordinary clusters—equilibrium structures optimized by geometry or energy.

The quataron concept solved the fundamental problem of deciphering the mechanism of crystal growth in an amazingly simple way (Askhabov 2016). Quatarons proved to be ideal building units for crystal growth. Due to the dynamism of structure, their inclusion into the crystal lattice occurs with virtually no kinetic resistance and deformation of the crystal lattice. The quataron model of crystal growth acts as an alternative to the known models of crystal growth by attaching individual atoms or ready crystalline blocks.

The development of ideas of the quataron concept opened a window to the protomineral world. And this world is today regarded as a new "world of neglected dimensions" (Askhabov 2017). As a result, the program of W. Ostwald receives a new impetus and focuses on the study of objects of the protomineral world. We must answer not only the questions of how minerals are formed, but also why they are formed, why minerals are exactly as they are. The ontogenesis of minerals should begin not with the origin of the mineral, but with the protomineral state of mineral matter.

Thus, the world of minerals is preceded by the world of specific pre-mineral objects —the protomineral world (Fig. 1). This world requires interdisciplinary approaches and new instrumental methods with spatial angstrom-nanometer and temporal femto-nanosecond resolution. In connection with the emergence of the protomineral world in the current agenda of mineralogical science, it is highly desirable to draw up a program of top-priority experiments for implementation with the European free electron laser - a device that is potentially able to satisfy requests of mineralogical science and study in detail the process at the source of mineral matter.

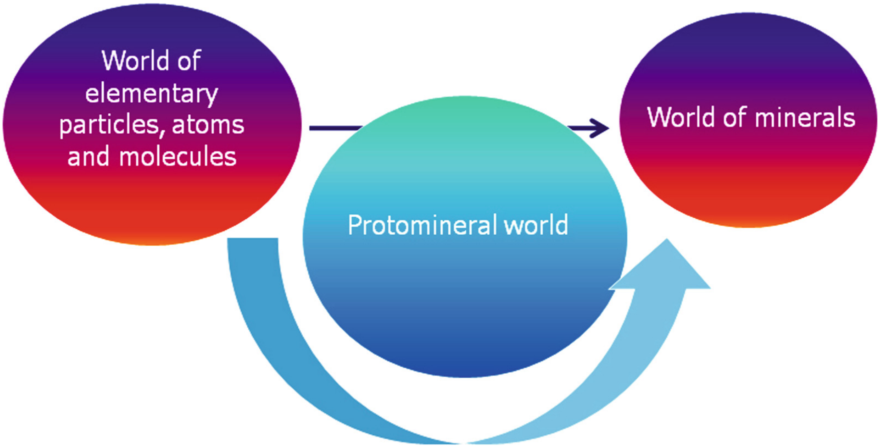

Fig. 1. Way from the world of separate atoms and molecules toward the world of mineral individuals comes through the protomineral world.

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