

Discussion

UDC 549.0

**ESSAYS ON FUNDAMENTAL AND GENETIC MINERALOGY:
1. WHAT ARE THE «MINERAL» AND «MINERAL SPECIES»?**

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At present, the existing nomenclature and systematisation of minerals is based on *chemical principles*, according to the statement that mineral is a chemical compound, though natural, but only one from million ones known to science. However, mineralogy is a *geological, natural-historic science*, and mineral is not only chemical compound but also a *natural geological body*, the main form of inanimate matter in nature, a stable phase of mineral-forming processes, which has its own geological history, the object of *geology*. Consequently, the nomenclature of minerals, their systematisation and classification must be *natural*, i.e. be based not only on formal descriptive laws of chemistry but also should reflect the real correlation of chemical composition and crystal structure of minerals with concrete geological conditions of their formation, as well as their evolution in geological processes. By analogy with other *natural science*, biology, it is shown that minerals as well as living organisms, can be studied at different levels of organization of matter, which are characterized by proper elementary discrete systems and phenomena. Special level is one of them, and system concept of *mineral species* is a genetic concept.

There is a conclusion that recommended formal merely *chemical* (or crystallochemical) criteria of the IMA CNMMN do not correspond to natural principles of classification of *mineral species*, and describe objects of mineral science from the one side, only at the level of inner structure of compounds, without taking into account the essence of mineral as a stable phase of geological processes, with natural variations of its chemical composition, structure and properties within the field of its stability.

17 references

Mineralogy, as a part of geological science, is a *natural-historical science*. It means that mineralogy studies *natural objects*, as they exist in nature (independently from interference, wishes or ideas of a human, in all their *complexity, diversity, and historical development*. In contrast from geochemistry, which deals with Earth crust substance at the level of chemical elements, mineralogy studies *compounds of chemical elements (minerals)*. Minerals are diverse. They differ not only by set of combining chemical elements but also by complexity of these compounds. As the main form of existence of inanimate matter in the nature, minerals *are originated, exist, and are destroyed*, i.e. «live» in the geological processes; reacting on changes of physical-chemical parameters of mineral-forming (or «mineral-keeping») medium, they, of course, can change morphology, chemical composition and structural peculiarities from their «birth» to «death».

A mineral is assumed to have crystal structure (it means that the structure can be detected by X-ray methods). Therefore metacolloids and other thin-dispersed formations, arising as a result of deceleration of germs growth, are excluded from a number of minerals as defective ones. This is the first of misunderstanding in mineralogy, the crystal structure of thin-dispersed aggregates exists and can be detected by more precise methods of electron.

All mentioned above fundamentally can help

us to distinguish the objects of mineralogy from the objects of chemistry. However, *chemical nomenclature and systematic of minerals* are generally based, as it was suggested by J. Berzelius in 1814 on chemical principles (Course of mineralogy, 1936; Frank-Kamenetskiy *et al.*, 1977; From Commission..., 1977; Bulakh, 1977, 1978, 2000, 2004; Lazarenko, 1978; Boki, 1978, 1997; Nickel, Grice, 1998; Nickel, 1992; Nickel, Grice, 1999, etc.). Chemists consider it *natural*, since, by their opinion, it «is simultaneously a law of nature» (Boki, 1985, 1997).

Mineralogists: who are they, geologists or chemists?

*«Widely chemistry extends its hands
in humane affairs...»*

D.I. Mendeleev

If we consider «minerals» only as a part of 15 million of «chemical compounds» synthesized by chemists, there is no problem. Their nomenclature and systematisation (classification), as well as the other chemistry objects, must be, of course, formalized by chemical laws, and new mineral names must correspond to the principals suggested by the International Union on Chemistry. For mineralogists-»chemists», considering minerals only as chemical compounds, this is quite normal. G.B. Boki (1997) wrote in his last work «Systematisation of natural sili-

cates» following: «It is possible to consider that a single attainment in classification of minerals for the last 100 years is that it was accepted to characterize minerals by chemical composition» (Page 3). «Mineralogy, although it is considered *as special science*, nevertheless represents a doctrine about inorganic compounds, forming our Earth, and *it is only a part of chemistry, on which ideas it is based entirely*» (Page 18, italics is our).

Academician A.E. Fersman did not agree with these ideas. A half a century ago he wrote: «Since study of mineral in all its properties, crystal, physical, mechanical and chemical properties, at the background of study the mineral not as a self-sufficient body, but as a part of a whole Earth's crusts, the mineralogy in our country has now come to raising of a number of the most important and profound problems of science. One should remember that mineral is not simply chemical compound from textbook on chemistry, but a natural body with all complexity of its laws and its history» (Fersman, 1945. Selected Works. V. 5. 1959. P. 552).

Distinctions between «chemical» and «geological» approaches in mineralogy are the most clearly revealed by determination of the main concept of mineralogy, «mineral species».

«Mineral species» is quite often considered *as the least* unit of organization of mineral matter (Lazarenko, 1961), «the most lower» taxon in systematisation, after G.B. Bokiy (1978, 1997). It seems to me to be wrong. «*Species*» should not be the least unit, but first of all *the comparable one* for all classes and groups of mineral with both simple and complicated composition and structure, in the whole mineral kingdom. It is not so, this is not a *species*, but *variety of species*, describing more «fine» distinctions, which can not be comparable directly for different minerals. So as *species-forming* features of mineral, the following ones should be chosen: first, *the most essential* ones, secondly, their *natural (genetic)* characteristics and properties.

What do mineralogists-»chemists» suggest us? Practically, to descent on elementary level and consider correlations of separate chemical elements in minerals. According to recommendations of the IMA CNMMN, the «*rule of 50 %*» is the main one determining boundaries between mineral species among continuous solid solutions, i.e. predominance («domination») of one of the chemical element over other ones (Frank-Kamenetskiy *et al.*, 1977; From Commission..., 1977). Recently the «*rule of 50%*» is extended even on ratios of elements in each of non-equivalent sites in the crystal structure of mineral (Nickel, Grice, 1998; Nickel, Grice, 1999). It is obvious this approach completely dis-

credits mineralogy as *geological science*, since in minerals with complex composition and crystal structure, in which there are more than ten cation structural sites, each of which can be isomorphically occupied up to a third by chemical elements of Mendeleev's table (for example, in eudialyte), it is possible to reveal an innumerable multitude of variants, and all them, according to recommendations of the CNMMN, can be registered as independent mineral species. However, from the point of view of geology, all of them are *eudialytes*, formed in quite definite field of stability under conditions of extremely high alkalinity of mineral-forming medium.

Nevertheless, this «subversive activity» of the CNMMN was delightfully accepted by some mineralogists. Provoking by these recommendations stream of «new minerals», for which names there is not enough mountains, rivers, and names of great scientists already, has flooded the literature, and threatening prognosis by A.P. Khomyakov (1990) to bring a number of mineral species to n 104 n 105 (basing on arithmetical calculation of possible combinations of chemical elements in crystal structures) becomes quite realizable. It is calculated that over 4000 minerals are described (Bokiy, 1997), and enthusiastic «selectionists» do not intend to stop on that. But it is time! A.E. Fersman (1938), and after him our and foreign prominent mineralogists-geologists as A.A. Saukov (1946), A.S. Povarennykh (1966), I. Kostov (1971), N.P. Yushkin (1977), V.S. Urusov (1983) *et al.*, explaining, what is the distinction of «*inanimate*» nature from «*animate*» one, repeatedly noted that a number of mineral species in nature is limited. A.E. Fersman, in particular, wrote: «A question about number of known in the Earth's crust mineral species obtains in whole more definite answer only at specification of the mineral species concept. M.N. Godlevskiy (1937) and A.G. Betekhtin (1937) absolutely properly introduced in the determination the physical-chemical principle, however, they could not avoid complications analysing dispersed-colloid systems and isomorphous mixtures. Merely formal approaches to classification of such multiphase systems are not applied; especially as mineral is a natural-historical body, for which absolutely specific and complex systems are appropriate and determined; especially as it is not possible to approach merely formal to subdivision of isomorphous series on independent species and varieties» (Fersman, 1938. Selected Works. V. 1. 1952. P. 846).

Mineralogists-geologists always objected to «chemical» formalism in delimitation of mineral species, they demanded its geological comprehension. A.K. Boldyrev (Course of mineralogy,

1936) admitted the «rule of 50%» for two-component compounds in case of continuity of a series, but in case of formation of intermediate compound he suggested to distinguish three phases (where «intermediate» phase could be isomorphous mixture, solid solution or chemical compound with variable composition) or consequently three mineral species in the following intervals of composition: 0-0.25, 0.25-0.75, and 0.75-100%. But he emphasized: «...if there is no more forcible bases for other subdivision» (!). However, if isomorphous mixture can not be satisfactorily described as two-component system, it is necessary to use triangle diagram for three-component system and to transform the «rule of 50%» into the «rule of 33%» (3 minerals); then in case of formation of «intermediate» compounds (7 minerals) the content of admixtures of other components in phases can not already exceed 17%. E.H. Nickel (Nickel, 1992) also points out that delimiting «point of 50%» transforms into «point of 33.3%» in three-component system (and in «25%» in four-component system), it is necessary to take into account at apportionment of single mineral species fields. So the delimitation of mineral species depends on choice of system for their description. That means that mineral species can not be correctly delimited in natural process without comprehension of this process.

D.P. Grigor'ev (1961) emphasized that concept of mineral species was formulated, basing on problem of classification of mineral individuals. This concept includes a multiplicity of individuals, which are chemically and structurally *identical*, but at the same time «minerogenesis does not seem now as passive deposit of mineral matter or body, but as a process of its development, in which correlated moments of origin, growth, and change of mineral, the signs of interaction of mineral and medium are traced... On the same basis the attention to questions of *development of mineral species, their changeability at minerogenesis under influence of changing factors: temperature, pressure, and chemism of medium* also becomes stronger» (italics is our).

Looking back to biologists

«...in every creation of nature we well see something that has long history...»

Ch. Darwin

G.B. Boki (1997) wrote that it is reasonable to compare the mineral classification with biological ones: «...objects of these classifications exists in nature independently from human

activity». However, he noted, «biological classifications are complicated by that a phenomenon of evolution must be take into account in either degree for them. This moment is absent in classification of minerals» (P. 9-10). Unfortunately, only adoption of hierarchy of biological taxons by him was the result of this comparison, i.e. subdivision of minerals into *classes, subclasses, orders, suborders, families, genera, and species*. Essence of biological systematisation, its *naturalness* and *genetic sense* of distinguishing of *biological species*, apparently, was not comprehended and estimated at its true worth.

First of all we should mention that in biology there is no generally accepted determination of the main concept, *living matter*, since (as they consider) there are no criteria having a single meaning, that distinguish *living* matter from *inanimate* one. Biologists are not confused by that (after all, only *objectively existing* things can be studied, but not the things, that we have *decided* to include or not include in the objects of our study), but in contrast to us, biologists clearly realize that they *study living matter at different systemic levels of organization of life: molecular* – «cellular» – «tissue» – «organogenetic» – «ontogenetic» – «population» – «specific» – «biogeocoenotic» – «biospherical», for which it is possible to distinguish proper elementary discrete *structures and phenomena* (Yablokov, Yusufov, 1989; Levitina, Levitin, 2002). The most important of them are molecular-genetic, ontogenetic, population-specific, and biogeocoenotic levels of study. At all levels the study of form of matter organization, i.e. chemical composition and structure of molecules, from which organisms consist, structure of cells, tissues, separate organs, morphology of organisms from embryo to adult individuals, species and populations of organisms, and, finally, natural their communities (biocoenoses), is accompanied by study of their development, clarification of their genesis and mechanisms of transmission of genetic information during subsequent evolution. It is very important.

Before we will consider *population-specific* level, the most interesting to us, we shall note that some our worrying «mineralogists-chemists» recently attempt to inspire us that all biological *specific* distinctions can be reduce to fundamental chemical differences in structure of DNA molecules and in due time «reduce all variety of organic world to *biochemical* (i.e. *chemical*) characteristics. And in foretaste of such perspectives they find the support to propagation of chemical classification also in mineralogy. This is a primitive simplification! Without possibility to go into details (look through – Levitina,

Levitin, 2002), we shall note that on *molecular-genetic level* in DNA molecules there are actually the special «parts», *genes*, controlling («encoding») their *reduplication*, i.e. break (with participation of special ferment of DNA-dependent RNA-polymerase) of hydrogen bonds between purine and pyrimidine bases jointing double spiral of DNA, and following synthesis of complementary threads (i.e. following «doubling» of each of broken threads of DNA). By this way «kept» in genes heritable information is really transmitted to intracellular controlling systems during synthesis of macromolecules of cellular protein of organisms on matrix principle. However, this transmission occurs by the way of *covariance reduplication*, i.e. self-reproduction with *changes*, the single specific for life on the Earth property, providing with appearance of endless number of changes (*mutations*), that are inherited, but not always kept in hereditary populations. At that the least element of arising mutations is not a gene, but one of joining pairs of nucleotides of DNA. At present, DNA molecules of *primitive* discrete living particles (viruses, phages, bacteria, protozoa eukaryotes) and free reproducing sexual cells of multicellular organisms are studied in details; they are really have *relatively high degree of stability*, that provides possibility of their identical self-reproduction (*hereditability*). But also it goes obligatory with *insertion of changes*, that results from physical-chemical properties of the most bulky DNA molecules, since *degree of stability* of each complex molecular and supermolecular system is *confined* and from time to time suffers *structural changes* as a result of movement of atoms and molecules. If these changes will not at once result in lethal outcome, they will, according to the law of Tumofeev-Resovsky, will repeatedly gain strength by the way of covariance reduplication, that *gives possibility of inheritance also discrete deviations from initial state*. Consequently, formation of species at molecular-biochemical level is connected both with stability and changeableness of DNA.

But speciation takes place not only at molecular-biochemical level. At *ontogenetic level*, during life of *individuals*, from their birth to death, not only realization of heritable information but also control of viability of this genotype of organisms by the way of natural selection take place. This is as if repeated natural experiment on continuation and evolution of live on the Earth.

We are, first of all, of course, interested in *population-species level* of organization of living matter. Concept *species* in biology was introduced by Aristotle (384-322 BC), and that became fundamental after the works of J. Ray (1627-1705)

and C. Linnaeus (1707-1778). However, conception about constancy, invariability of species at once resulted in creationism, i.e. ideas of their divine creation. In struggle against creationism the transformism of G.-L. Leclerc, comte de Buffon (1707-1788) and J.B. Lamarck (1744-1829) has been formed, and soon every changeability of organisms in nature was identified with speciation. (How it is known on that now happens in mineralogy.) In the beginning of 20th century, *typological conception about indivisibility of species has failed* finally, and not the species, but the concept of *geographical* race has become the main unit of classification in biology, i.e. binominal nomenclature was replaced by trinomial one, where besides *genus* and *species* even *subspecies* was included in. (For example, *Vulpes vulpes vulpes* – Fox Middle Russian, *V. vulpes stepensis* – Fox Steppe.) When it was found out that subspecies were also inconstant, one became to distinguish *seasonal, ecological, physiological* and *other races*. As a result, traditional «Linnaeus's» species was disintegrated into hundreds and thousands hereditably stable small forms. For example, species of wheat ordinary, *Triticum vulgare* Vill., was divided into several thousands smaller species. This situation resulted in that fundamental biological concept *species*, it seemed, was outdated (Yablokov, Yusufov, 1989).

Only in the beginning of 30th years of the 20th century, thank to the works of schools of N.I. Vavilov in the USSR and J. Clausen in the USA, the problem of species became approaching to its contemporary solution: *biological conception* of species has been created. Species has appeared to be a complex *genetic* system: individuals of one species have the same genofund and are defended from penetration of genes of other species by natural barriers of isolation. It has appeared, that *species* can include different by structure and the way of life forms (*subspecies, populations*), which representatives can from time to time interbreed and give fruitful posterity. That is transitions between species, subspecies, and populations are possible. These is the contemporary conception of *polytypical species*, that unites contradictory points of view on *species*, as the *main structural unit of organic world*, and *on species*, as complex developing *genetic system*. According to A.V. Yablokov and A.G. Yusufov (1989), species is a *multiplicity of individuals with general morphophysiological characteristics, which are able to cross with each other, giving fruitful posterity, and form a system of populations, forming general natural habitat*. However, neither *morphological nor geographical and physiological-biochemical* distinctions separately can not serve universal specific char-

acteristics. That is the genetic unity of organisms turns out the main *criterion of species*. *Species turn out not genetically exclusive (closed), but genetically stable systems*. We shall not consider *phylogeny of species*, it is clear that for time of existence of life on the Earth not only biological species but also their single genera, classes, and even types of organisms have evolved.

Mineral at different levels of organization of mineral matter

«Mineral is not only physical-chemical system, it is a natural body, part of the most complicated geological environment, and must be studied only in connexion with these environment, in all complex analysis of that numerous factors, from which it is composed.»

A.E. Fersman

We suppose that in mineralogy, by analogy with biology, it is possible to distinguish different levels of study of mineral matter, that will allow better determining the place of the concept *mineral species* among other nomenclature units.

1. *Atomic-crystallochemical level*. This is, in fact, that is known to all mineralogists and that they are occupied. From analogies with biology it is evident that on this level in mineralogy its own *elementary discrete structures* — i.e. atoms and their groups, and *phenomena* — i.e. jointing them in crystals structures with «chemical» bounds of different type, can be distinguished. But it is not yet the *mineral species*. Just as both in biochemistry far from all can be reduced to structure of DNA molecules, but successively forming as a result of synthesis of protein *cells, tissues, organs* of organisms are specially studied, and in mineralogy atomic structures of matter and regularities of behaviour in them *separate atoms* as well as isolated discrete *groups of atoms* (for example, SiO_4 -tetrahedra) are studied: polymerisation of tetrahedra in diortho-, different chain, banded, layer and framework radicals, their joining with heterosize and heterocharge cations. Translation of these elements (on matrix principle) in space to endless crystal structures allows distinguishing the periods of identity and *unit cells*. As in biology, during the process of mineral growth, at transition from structures of near order (unit cells) to structures of long-range order (macrovolumes of matter), variations appear and can be transmitted (compare with mutations): defects, dislocations, errors in packing of atoms (polytypism), substitution of SiO_4 tetrahedra by AlO_4 , FeO_4 , BO_4 , PO_4 tetrahedra, and substitution of cations by microadmixture elements (isomorphism), inclu-

sion of whole fragments of one structure in another one (domain structure, polysomatism), chemical and structural ordering of atoms (for example, Si/Al-ordering in the framework of feldspars and other aluminosilicates), twinning, etc.

Just as living organisms, minerals are distinguished by degree of complexity of their organization: there are native elements (analogues of primitive unicellular organisms), intermetallics, mineral with simple and more complex variable composition, representing solid solutions, isomorphous series, structures with mixed radicals, mixed-layer silicates, «cellular» zeolite-like structures, silicates with broken frameworks, etc., these are the result of complicated adaptation of crystallizing mineral phase to changing by chemical composition and properties mineral-forming medium.

Matrix structure of crystal structure of minerals is described by space symmetry in of atoms pattern. Besides 14 known types of cells of A. Bravais, 32 species of symmetry, and 230 standard space groups of E.S. Fedorov, recently the non-standard space groups are distinguished; besides *general* symmetry of structure *the local* symmetry of its separate fragments is distinguished. The latter is especially important for description of coordination of microadmixture in defects of crystals by spectroscopic methods of analysis and for explanation some physical properties of minerals. *The symmetry* of short-range and long-range order is distinguished, that reflects distinctions in structure of micro- (in unit cell) and macrovolume of mineral matter. It is clearly that symmetry reflects abstract order in arrangement of atoms in structure, and its change can be caused by different reasons, i.e. it is secondary and can not be the main factor for mineral species determination.

2. *Ontogenetic level*. Just as in biology, at this level the regularities of growth of single individuals, crystals (grains) and their aggregates, are studied. Detailed review of studies at that level is given in «Ontogeny» by D.P. Grigor'ev (1961): from origin of germs to different types of growth and recrystallization of individuals and aggregates. It is important for us that a crystal evolves during process of growth: its morphology, chemical composition, peculiarities of crystal structure, symmetry can be changed, the zones of growth or face sectors, which can be essentially different on chemical composition and properties can appear. Since, according to E.K. Lazarenko (1963), *mineral species is a multiplicity of mineral individuals of the same type structure and composition, changing in definite natural limits, then individuals characterized by continuous isomorphism should be considered as the sin-*

gle mineral species, and the other individual members of this series as the varieties of this species. It does not matter whether the content of isomorphous admixture exceeds 50 % or not (moreover, in separate structure site), since the real mineral matter and real variations of its composition during change of physical-chemical conditions of mineral-forming medium are studied. In biology *species* is a *totality of individuals*. Therefore reverse cases, when within the same mineral individual (crystal, grain) the several mineral species are detected in separate growth zones or crystal sectors (for example, hafnon in growth zones of zircon, in which Hf:Zr > 50:50), by our opinion, are a nomenclature absurdity. Studies at ontogenetic level must include also solid phase transformations inside individuals (phase disintegration, polymorphous transitions, structural ordering, microtwinning), since they take place during change of conditions on certain stage of *existence* of mineral individual, although after its crystallization. That brings in its own complications in the problem of separation and delimitation of mineral species, but that is the real construction of studied mineral matter.

3. *Species level*, to which we has already turned and which is the main goal of this study, is summoned to determine criteria, by which unit *mineral species* should be distinguished as well as, and *species varieties of mineral species*. By analogues with biology it is possible to make a number of conclusions. First, *species* is a *genetic concept*, and its content is determined not only by chemical composition and crystal structure but mainly by behaviour in geological processes. We do not know *phylogeny* of mineral species: when, how, and in what forms did chemical elements combine chemical compounds on the Earth, what was physical-chemical conditions and how did they evolve. But we know that the same chemical elements at high pressures and temperatures form absolutely different compounds, than under moderate and hypergene conditions especially. We know that chemical elements of the Earth have been separated, or have been differentiated in some way. Much better (although far from all groups) we know *ontogeny* of minerals. If there are not enough natural observations, the physical-chemical experiments and synthesis of lost, relic, unstable compounds help us. They help us to recreate, reconstruct minerals on early stages of their existence. Just as a result of ontogenetic studies we detect the real totalities of evolving mineral individuals, which we can unite in really existing mineral species. By our opinion, *mineral species is a natural totality of mineral individuals, which, in the bounds of field of its stability, are able to*

change, in certain limits, both chemical composition and peculiarities of crystal structure in accordance with change of physical-chemical conditions of mineral-forming (mineral-keeping) medium, since beyond this field they are destroyed and replaced by other minerals.

Second, *species* is a main, *commensurable* nomenclature unit, but it is *not the least*: in biology within the species the *subspecies* (our *varieties*), sorts, races, populations are distinguished, which in biological classification are not less significant, than species. The same is expediently to distinguish among minerals, for description of matter at different stages of process or in different geological environment. *Varieties* by chemical composition, structure, morphology, way of formation, etc. in mineralogical nomenclature should become more significant in study of analysis of mineral typomorphism for example.

Third, different groups of minerals are distinguished by complexity of their organization as well as living organisms, for which it is impossible to distinguish *all species-forming characteristics*, and the main criterion is *an ability to reproduce the self-similar*; apparently, in different groups of minerals it is also justified to distinguish mineral species on their own criteria, without adjustment their to universal templates.

Mineral *species* is an abstract concept, but it generalizes and «absorb» the properties and behaviour of concrete mineral individuals. Since this is a crystal phase in mineral-forming process, it is separated from co-existing phases by *division surface*. The presence of distinct division surface is the main criterion for determination of mineral species. Growth zones and face sectors do not have the division surface and belong to the single mineral individual including them, and, consequently, they are considered as the same mineral species. On the other hand, the products of phase disintegration (for example, perthites) have the division surface, so microcline and albite co-existing inside the single block-crystal of feldspar are different mineral species. However, on early high-temperature stage of phase disintegration co-existing K,Na- and Na,K-feldspars (with high content of isomorphous admixture of opposite component) during their X-ray study reveal distinctions in unit cell parameters *a* at equality of both parameters *b* and *c*, that shows the reservation of general Si,Al-framework in «disintegrated» feldspar. It is evident, in that case we do not have a right to distinguish microcline and albite phases, and have to do with one mineral species — K,Na-feldspar. The latter shows that content of a concept mineral species is concrete and can change at different

physical-chemical parameters.

And the latter. From stated above it is obvious that «new minerals» registered by the IMA CNMMN, studied only by chemical and structural methods, are most often the varieties of already known minerals, since they are connected with gradual variations of chemical composition with local reconstruction of symmetry of sites during their occupation by isomorphous admixtures (Borutzky, 1997). Detailed study of their behaviour in geological processes concretizes data about real minerals and their groups, that newest recommendations of the IMA CNMMN become simply absurd. These rules, as a matter of fact, are modest cover of our *lack of knowledge* of minerals.

Conclusions

Thus, main misunderstandings concerning nomenclature in mineralogy are caused by the fact that many researches do not comprehend that mineralogy, as a part of geology, is a *natural-historical science*, and consequently, the concept of *mineral species* is a *genetic concept*. If this statement is accepted, then several conclusions follow from this:

1. Study of mineral matter is made at different organizational levels. The objects of this study – atoms, their complexes chemically bonded, structure, symmetry, defects, crystals, their aggregates, mineral species and individuals, varieties, and studied phenomena – isomorphism, polysomatism, polytypism, polymorphism, crystallization, growth of crystals, metasomatism, solid phase transformations, typomorphism, etc. are different at different levels. For each of them their own classifications are possible (systematisations of chemical compounds, structures, defects, etc.), reflecting the present day knowledge of crystallochemistry, physics of minerals, etc. Limitation of mineralogical science by study of minerals only at one level (for example, *chemical*), its transformation only in descriptive science, readdress of study of behaviour of minerals in geological processes to other sciences, petrology, lithology, geochemistry, by our opinion, result in transformation of mineralogy in chemistry and its extermination as geological science.

2. Study of minerals at *species* level reflects their behaviour as a phase of geological processes, the main form of existence of inanimate matter in nature. *Mineral species* is a multiplicity of mineral individuals, really existing in the certain *field of stability*, within the limits of which both *chemical composition and peculiarities of crystal*

structure can change (according to the change of physical-chemical parameters of medium) but the species does not exist (*destroyed or replaced by other minerals*) *beyond the field of stability*. Isomorphous substitutions really observed in structure (independently from that whether they result in domination of some component or not), cases of zoned or sectored growth, chemical or structural ordering, polytypism, etc. do not result in formation of independent mineral species, if they occur within the field of stability.

3. *Mineral species* is not *the least*, but *comparable* nomenclature unit. With the purpose of detailed description of behaviour of minerals within the field of their stability the corresponding conventional varieties on morphology, chemical composition, structure, physical and spectroscopic properties, etc. can be distinguished. Determination of varieties is not less significant in mineralogy, than determination of mineral species.

4. Delimitation and distinguishing of new mineral species can be realized as a result of detailed physical-chemical study of minerals, obtaining and publication of evidences of independent existence of corresponding mineral phases in any concrete geological environment, but not as a result of volitional decision of some commissions, notwithstanding authoritative researches forming them are.

The work was supported by the Russian Foundation for Basic Research (project 03-05-64139).

References

- Bokiy G.B.* To the question of determination of main concepts of mineralogy // Main Concepts of Mineralogy. (Osnovnye Ponyatiya Mineralogii). Kiev: Naukova Dumka. **1978**. P. 11-16. (Rus.).
- Bokiy G.B.* Perspective of creation of natural classification of chemical compounds, including minerals // Tr. In-ta Geol. and Geofiz. Novosibirsk. **1985**. N. 610. P. 1-11. (Rus.).
- Bokiy G.B.* Systematisation of natural silicates // Itogi Nauki i Tekhniki. Ser. Kristalloghimiya. V. 31. M.: VINITI, ZAO «ASTR-KOSMOSINFORM». **1997**. 192 p. (Rus.).
- Borutzky B.Ye.* About minerals of variable composition with variable structure // Tez. Dokl. k IX S'ezdu Mineralogicheskogo Obshchestva pri RAN, Posvyashchennomu 275-letiyu Rossiiskoi Akademii Nauk. Saint-Petersburg. **1999**. P. 201. (Rus.).
- Bulakh A.G.* To principles of determination of concepts «mineral» and «mineral species» and