# GEOCHEMICAL MINERALOGY BY VLADIMIR IVANOVICH VERNADSKY AND THE PRESENT TIMES

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The world generally believes that "*the science of science*" about natural matter – *mineralogy* – became obsolete and was replaced by the new science – *geochemistry*, by V.I. Vernadsky. This is not true. Geochemistry was and is never separated from mineralogy – its fundament. Geochemistry studies behaviour of chemical elements mainly within the minerals, which are the basic form of inorganic (lifeless) substance existence on the Earth conditions. It also studies redistribution of chemical elements between co-existing minerals and within the minerals, by variable conditions of *mineral-forming* medium during the *mineral-forming* processes. On the other hand, owing to V.I. Vernadsky, mineralogy became geochemical mineralogy, as it took in the ideas and methods of chemistry, which enables to determine chemical composition, structure and transformation of minerals during the certain geological processes in the Earth history.
1 photo, 20 references.
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Vladimir Ivanovich Vernadsky's remarkable personality and his input to the Earth sciences, first of all, to mineralogy – changing it from the trendy mineral collecting hobby, observation of mineral beauty, art and culture areas into the *mineralogical science*, are not to be expressed. Even at present, over a century since, his studies impress with its full of thought, unity, systematic character and wide approach to investigation of natural objects, deep analysis of previous publications in this area. His activity amazes with unusual dedication and uncompromisingness for organization research and fight with traditional conservatism, with solution of principal issues of science and with creation of progressive scientific mineralogical school in Russia. Scientific ideas by Vernadsky are actual at present not less, but even more than 100 years ago, when not all the mineralogists could accept and understand them. According to Dmitriy Ivanovich Scherbakov's memoirs: "*Vladimir Ivanovich in his addictive aspiration forward was often taking the lead over scientific ideas of his epoch. Sometimes he was not understood and his thoughts were underestimated by his contemporaries. But his outstanding scientific intuition always lead him by the right way and his clear-sightedness helped to create the number of new leading courses with perspective future*" (Scherbakov, 1963, p. 34, 35).

## Vladimir I. Vernadsky – as a mineralogist

As to the memoirs by Boris Leonidovich Lichkov (Lichkov, 1948; 1963), scientific creative work of V.I. Vernadsky could be divided into several stages. Forming his personality of scientist-mineralogist and the main input into reformation of Russian mineralogy and creation of mineralogical science in Russia are related with the early, "Moscow" stage (1988–1909). At that time, on the recommendation of professor Alexey Petrovich Pavlov, Vladimir Ivanovich was invited to occupy the post of associate professor in mineralogy at the mineralogical department at the Moscow State University, for giving lectures in mineralogy at the natural history faculty (1890). Since 1891 he became a director of Mineral cabinet and since 1892 became the head of the department and started giving lectures in mineralogy, crystallography and natural history both at the natural department of the physics-mathematical faculty and in mineralogy at the medical faculty and also (since 1901) – at the Moscow high women's courses. During that time (1891) he defended his thesis for a mastery's degree in geology and geognosy, the topic is "*On sillimanite group and the role of alumina in silicates*" (Vernadsky, 1891). Later he obtained his PhD on the theme "*Phenomena of sliding of crystal matter (physics-crystallographic study*" (Vernadsky, 1897).

The fundament of those lectures (which were later re-published as textbooks) and scientific generalizations was strict unified methodology, which was not accidental, sudden happy striking, but it resulted from the huge, purposeful work. Vernadsky analysed in detail what was done by different scientists from different countries to reveal trends in development of scientific ideas, collective input in the whole image of knowledge of construction and laws of the environment, of the Universe. We will not replicate

the scientist's well-known biography facts, but will mention only those, which are necessary for the topic of this paper and our grounds for us characterizing *mineralogy* of Vernadsky as *geochemical* mineralogy and not *geochemistry*. As the basic documents we will cite scientific works by Vernadsky himself, his letters and testimonies of his contemporaries.

First of all, Vladimir Ivanovich had brilliant teachers at the Saint-Petersburg University, which he was graduated from in 1885 at the natural history department of physics-mathematical faculty. His tutors were outstanding Russian scientists, who contributed a lot into the world science. The lecturer and examiner in chemistry was Dmitriy Ivanovich Mendeleev – the creator of Periodic Table of chemical elements. Lectures in geology and mineralogy were given by Vassiliy Vassilyevich Dokuchaev – the founder of revolutionary new direction in soil science. Under his tuition Vernadsky practised in the fieldwork, studying soils of Nizhegorodskaya and Poltavskaya provinces, with geological mapping; and also actively worked in Mineralogical cabinet of the University. Still being a student, he was interested in problems of mineral genesis, which he described in Brockhaus and Efron Encyclopedic Dictionary (Vernadsky, 1892). His tutor was also Sergey Fedorovich Glinka – who supported traditional views in mineralogy, however brilliant mineral expert.

After graduating from the University, Vladimir Ivanovich obtained a position of the keeper of the Mineral cabinet and after successful passing his masters exam (1887) he was appreciated with the overseas trip (1988).

It is usually considered that he was busy with deep studying crystallography there and since that sometimes "Moscow" stage is subdivided into two: *crystallographic* and *mineralogical*. But it is not quite, as we can read from the Vernadsky's detailed autobiographical abstract to the 4th edition of his lectures he gave at the Moscow University in 1910–1912: "*Almost all mineralogy departments at the universities and high technical and medical schools were occupied with not mineralogists, but geologists... Me myself, the follower of V.V. Dokuchaev and S.F. Glinka at the Petersburg University, got the scientific training in methods of research only abroad, in Munich and Paris*" (Vernadsky, Kurbatov, 1937, p. 38). This edition was prepared in cooperation with Sergey Mikhailovich Kurbatov under the title "*The Earth silicates, aluminosilicates and their analogues*".

Thus, Vernadsky considered western countries as providers of progressive trends in mineralogy and crystallography and new methods of research should be learnt there, in advanced as to Russian development.

*Fig. 1. Vladimir Ivanovich Vernadsky. Photo 1905 year.*

After a short visit at the foreign corresponding member of the Imperial Russian academy of science, professor Archangello Skakki, Vladimir Ivanovich moved to Munich for visiting well-known mineralogist and crystallographer, professor Paul Groth and physicist crystallographer Leonard Zonke. At Groth's laboratory (1888–1889) he synthesised triethyl ester of trimesic acid, which seems to have nothing in common with mineralogy. But the essentials are that Groth was the first who understood and decided to express an idea that crystal can be described simultaneously both as molecule of chemical compound (which until nowadays remains as empirical chemical formula of the mineral) and endless three-dimensional pattern with atoms in lattice points. At that time he was busy with this problem since 1870s and then was first who understood and promoted in self-founded magazine Zeitschrift für Krystallographie the works by Evgraf Stepanovich Fedorov, who was repelled in Russia and Arthur Moritz Schoenflies. Later Groth was one of the initiators of X-ray analysis application in mineralogy, after professor of physics Max von Laue proved the possibility of diffraction of X-rays on crystal lattice and in 1912 in presence of Groth and with assistance of Walter Friedrich and Paul Knipping obtained the first X-ray picture of halite.

Describing the fundamental changes in crystallography Vladimir Ivanovich wrote: "*At*

*the end of the XIX and beginning of the XX century in crystallography there was formed new precise geometrical conception about crystal, which replaced the previous idea about crystal polyhedra. Crystal is considered to be an endless system of homologous points within space, which distribution meets the basic geometric characteristics of crystal polyhedra — their symmetry and the law of rational indices. The background of such ideas about crystal can be traced in XVIII century, in works by Bergman and Hahn[1], general conclusions by Haüy[2]. Now we see that the discovery of cleavage made by Hahn, was the fundament of all the theoretical thinking of the century long. Finally, it was crowned with the complete mathematical theory of possible systems of homologous points within space, it was presented independently: analytically — by professor Evgraf S. Fedorov in St.-Petersburg (1888—1891) and geometrically — by Arthur Schönflies in Stuttgart. They both obtained the same result — 230 systems of such points, which could be brought to fractional divisions. All the crystallographic groups were found earlier (Johann F. Hessel[3], 1830—1832, Auguste Bravais[4], 1851—1914, L. Zonke, 1879—1885) occurred to be the subcase of this remarkable and unique mathematical construction. ... The newly created concept was not in accord with the usual but experimentally unproved belief that chemical compound must be presented with molecule. In fact, this was absolutely new approach to the scientific understanding of matter solid phase — crystal one — chemical compounds, determined or undetermined. This approach was different rather than thermodynamic ideas, the approach enabled to bring together solid phase substances to investigation of their atomic structure"* (Vernadsky, Kurbatov, 1937, p. 10).

In March 1889 Vernadsky had moved to Paris where he worked under supervision of professor of natural history and inorganic chemistry Ferdinand A. Fougué in Collège de France and of professor of general chemistry, physicist and chemist Henri Louis Le Chatelier — the author of theory of dynamic equilibrium in thermodynamics and also the discoverer of pyrometer and metallographic microscope, in École des Mines. Vernadsky studied methods of pyrometry, synthesized minerals and studied their optical properties; also he was interested in natural forms of silicon and aluminium — the most important chemical elements on Earth. The latter was the basis of his above mentioned Masters dissertation (Vernadsky, 1891) and later this investigation was the central one amongst his innovative studies of the huge group of petrologically important aluminosilicates, which resulted in explanation of relation between their structure and chemical composition.

Recalling that time in the letter to Alexander E. Fersman from Carlsbad dated 1 October 1935, Vladimir Ivanovich wrote: *"All my scientific past is going over again. Both work and wishes, failed to be fulfilled — about structural chemistry of aluminium and silicon — work with Le Chatelier and Fougué and then — interest in polymorphism where a little was done about, postponed till better times, when at the beginning of a century I left for mineralogy as dynamic discipline and then — for geochemistry"* (Letters..., 1985, № 139, p. 173—175).

However, was everything that bad at the Moscow University when Vernadsky came? What was the real level of Russian mineralogy?

The impression about this can be based on the jubilee "Geologic almanac" (2003), published to 250th anniversary of Moscow State University. The authors recall that Moscow University, founded according to the Decree of Empress Elizaveta Petrovna from 12 (25) January 1755, consisted of three faculties: faculty of law, medicine and philosophy. Department of natural sciences was within the Medical faculty and at that time it had excellent mineral cabinet. It was donated to the University by the Urals industrialist Nikita Akinfiyevich Demidov and compiled on the basis of collection acquired by Akinfiy Nikitich Demidov in Saxony, from professor of Freiberg Bergakademie Heckel. There were nearly 6000 specimens in the "Heckel mineral cabinet", supplemented with specimens from the Urals and Siberia, but in charge of this collection was not a mineralogist, but famous writer — Mikhail Matveyevich Kheraskov. At the beginning, classes in mineralogy were available at two faculties — medical and faculty of philosophy; lectures in mineralogy were given since 1758 by German professor Johann Christian Kerstens, then since 1769 — by Matvey Ivanovich Afonin, who had studied abroad, at the universities of Königsberg and Sweden.

[1] — Otto Hahn (1879—1968) — German physicist and radiochemist, discovered nuclear isometrism and uranium fission. In 1944 was awarded with the Nobel Prize.
[2] — René Just Haüy (1743—1822) — French mineralogist, the founder of crystallography, presented the law of whole numbers and the basic law of crystallography — the law of rational intercepts.
[3] — Johann Friedrich Christian Hessel (1796—1872) — German scientist, professor of mineralogy, worked at the Marburg University.
[4] — Auguste Bravais (1811—1863) — French physicist, one of the founders of crystallography, initiated the geometrical theory of structure, established 14 Bravais lattices.

In 1804 there was established new division of physics and mathematics and another one department of mineralogy within it — the department of mineralogy and agriculture. The heads of this department were graduates of the University Anton Antonovich Prokopovich (1804—1818) and Mikhail Grigoryevich Pavlov (1820—1835). At the same time the department of natural history at the faculty of medicine was transformed into the "Demidov" department of natural history on the basis of "Semyaticheskiy mineral cabinet" donated by Czar Alexander I. This mineral cabinet was acquired from prince Yablonovskiy for 50000 Netherlands guilders and handed over by the Urals industrialist Pavel Grigaryevich Demidov, according to the family traditions, with the splendid private mineral museum, library and transferring professors position, which was occupied for 30 years (from 1804 till 1834) by German professor Johann Gotthelf Fischer von Waldheim (in Russian — Grigoriy Ivanovich). During that period he brought many innovations to the education, for instance, practical classes with students on the basis of museum specimens and excursions to the Moscow suburbs. Fischer von Waldheim wrote and published two-volume text-book in mineralogy (1812 and 1820). In 1805 he organized Moscow society of naturalists (MOIP), that became the platform for propaganda of new ideas in mineralogy by Vernadsky and Fersman and it's Magazine ("Proceedings of MOIP" — since 1806, "Memoirs of MOIP" — since 1809 and "Bulletin of MOIP" — since 1829). He was the director of Museum of natural history from 1805 till 1834. Later, the position of the Head of "Demidov" department occupied Alexey Leontyevich Lovetskiy, who gave lectures in mineralogy from 1824 till 1840 and in 1832 offered the innovative mineral classification by their chemical, physical and crystallographic features. Unfortunately, the comprehensive Mineral cabinet suffered from the Moscow fire of 1812, but in 1813 was reconstructed owing to the collection donated by Nikolay Nikolayevich Demidov.

Since 1835 the courses in mineralogy and geognosy became independent in Moscow University and after integration of two departments: of mineralogy and agriculture of the physics-mathematical division and "Demidov" of medical faculty, there occurred the new department of "mineralogy and geognosy". The head of that department was Grigoriy Efimovich Schurovskiy (until 1861) and Mineral cabinet, previously based at the Natural history museum since 1839, in 1846 became independent too and was transferred to the department of mineralogy and geognosy, under supervision of Charles Frantzévitch Roulier. Even though Schurovskiy was mostly interested in geology, his lectures in mineralogy were remarkably professional, with demonstration of facts and critical revision of existing theories. Under Schurovskiy's proposal, in 1863 department of mineralogy became independent within the division of physics and mathematics, even though it was not officially established until 1870 due to the absence of professor of mineralogy. Since 1861 lectures in mineralogy were given by Mikhail Aleksandrovich Tolstopyatov, but he was appointed to the job (on the 7$^{th}$ (20$^{th}$) March 1870) only after he obtained his Doctoral degree in 1869; he was occupying this position will his death in 1890 (i.e. until Vladimir I. Vernadsky). He created a good collection of minerals and crystallographic models in the Mineral cabinet, his lectures in mineralogy were brilliant and also in 1887 he founded chemical laboratory at the department, for analysis of minerals; so that way he went down in history as the founder of experimental mineralogy and crystallography.

Thus, it is hard to agree with Alexander E. Fersman saying that *"all the predecessors of Vladimir Ivanovich on the post of head of geology and mineralogy department, Fischer von Waldheim, Schurovskiy and Tolstopyatov were the strangers to innovations"* (Fersman, 1946). Apparently, this reproach is unfair — the lecturers at the University took so much effort to make both mineralogy as a science and mineralogical department at the Moscow University independent, 20 years prior to Vernadsky's presence. However, in comparison with what Vladimir Ivanovich experienced in Europe, it was seemingly incomplete. He wrote: *"At the Moscow University long before me the head of the mineralogy department was M.A. Tolstopyatov (since 1868), who did not work in science, palaeontologist by education and the first professor of mineralogy, after G.E. Schurovskiy*[5]*. It can be said, that there was no mineralogy at the proper scientific level of that time at the Moscow University... In Moscow I found newly equipped chemical laboratory at the Mineral cabinet, which M.A. Tolstopyatov faught out from the faculty, on the initiative of his friend E.D. Kislakovskiy*[6]*...*

[5] — Both theses by M.A. Tolstopyatov were on crystallography and were the summarized literature data. He was an amateur mineralogist and a brilliant lecturer, made up a good mineral collection. After his death his interesting observations of the beryl crystals morphology were published.

[6] — Yevgeniy Diodorovich Kislakovskiy — the keeper of the Mineral cabinet at the Moscow University in the time of M.A. Tolstopyatov.

*V.V. Dokuchaev, one of the greatest naturalists, was a geologist and at that time was busy creating a new tendency of universal importance in soil science, where I was granted to take part in. But his lectures in mineralogy were not trivial. He stressed on the dynamic meaning of mineralogy and this was the major difference between his lectures and teaching mineralogy at home and abroad. In that respect I became his follower, bringing physics of solids — as a separate science into teaching crystallography and mineralogy — as a history of minerals of the Earth's crust, proceeding with the course by Comte de Buffon and not by Linneaus, which was dominant everywhere at that time"* (Vernadsky, Kurbatov, 1937, p. 28).

In fact, Carl Linneaus was a world trend-setter at that time, who divided all the natural occurrences into three kingdoms: animals, plants and minerals, with an idea about constancy and stability of the species, which naturally led directly to creationism — an idea of divine creation. But Vernadsky was already firmly following the positions of transformism by Georges-Louis Leclerc Comte de Buffon and Jean-Baptiste Pierre Antoine de Monet Lamarck who proved variability of species under conditions of existence conditions and changes in the environment; that was explained by Charles Darwin that *"we regard every production of nature as the beginning of having a long history"*. We will add to this that in 1910 there were discovered only 82 chemical elements out of 115. Radioactivity was discovered not long ago and studies of diffraction on crystal lattice nearly began. It became apparent, that the natural form of existence of chemical elements is atoms, but their bonds within the mineral crystal structure were not determined yet. 230 Fedorov space systems deduced were not identified with the real atoms (or ions) within the structure. And the preliminary conclusion by Vernadsky about *"geochemistry that studies atoms within the Earth's crust and mineralogy — molecules"* was the gained revelation that could become the fundament for radical reformation of mineralogical science by revision of all the data accumulated.

## Vernadsky's mineralogy

Vernadsky's appointment to be the head of the mineralogy department (1890—1911) gave start to the golden age of mineralogy and crystallography at the Moscow University. The Moscow (later the pan-Russian) mineralogical school rose from the small Mineral cabinet into the scientific centre of mineralogical research with the first-class equipment and world-level scientific achievements. One of the largest Russian mineralogical museums, replenished with Rumyantsev's collection of minerals, was organised (Geological almanac, 2003).

First of all, it was necessary to write textbooks according to the new scientific ideas and to educate new specialists in mineralogy, which Vladimir Ivanovich drew out of his students (Popov, 1963). His first students were Anatoliy Orestovich Shklyarevskiy and A.A. Aunovskiy, later — the 1897s graduates Sergey Platonovich Popov, Pavel Karlovich Alexat and Vladimir Georgiyevich Orlovskiy; Yakov Vladimirovich Samoylov from Odessa and Nikolay Nikolayevich Tikhonovich from Khar'kov; and also Yelizaveta Dmitrievna Revutskaya and Anna Boleslavovna Missuna — the graduates from the Moscow high women's courses. Later the number of the followers and staff of the Mineral cabinet rapidly increased, the new specialists were Nikolay Ivanovich Surgunov, Vladimir Vasilyevich Arshinov, Vissarion Vissarionovich Karandeev, Vladimir Victorovich Kritskiy, Konstantin Avtonomovich Nenadkevich, Leonid Lakrionovich Ivanov, Pavel Prokopyevich Pilipenko, Olga Mikhailovna Shubnikova, later — Genrikh Iosifovich Kasperovich and Alexander Yevgenyevich Fersman. The majority of the followers of Vladimir Ivanovich later had become the prominent scientists.

Vladimir I. Vernadsky creates his textbooks on the basis of his own lectures in mineralogy and crystallography, he gave to the medical and natural history students from 1891 to 1912, consequently corrected and supplemented, published on every possible occasion. What was the difference between them and the generally accepted mineralogy course at that time? Even in 1891 Vladimir Ivanovich cited some phrases from the three-volume book by Jöns Jacob Berzelius published in 1822, as an epigraph to his Masters dissertation: *"Mineralogy as a science about inorganic compounds comprising our Earth, is only a part of chemistry, which is its comprehensive and historical fundament"*.

As we know, the description of every mineral as a natural compound must include characteristics of its chemical composition, crystal structure and conditions of formation — certainly, if we consider it as an object of scientific investigation and not as an object of arts, interior or collection, which interest mostly amateurs. Such a complex description of a mineral did not exist prior to Vernadsky — mineralogy "terminated" in its evolution in detailed description of crystal faces and habitus and its physical properties (density,

hardness, cleavage, color, luster, transparency). The necessity of above mentioned three major characteristics of the mineral substance was first declared by V.I. Vernadsky, even though the chemistry's key role: *"It seems to me that all the future evolution of crystallochemistry should be in close cooperation with chemical mineralogy and chemistry in general. Mineralogist and crystallochemist have to work together. ...The data of crystallochemistry and data of chemical mineralogy should correspond to each other. The data of chemical mineralogy — not only as a stoichiometric formula — should be initial for calculation the space atomic formula. Where this was not done, the space atomic formulas should be considered as undetermined and have to be refined. All the crystallochemistry is in such a state now, but for the simpler compounds this is not of big issue, however for the groups like silicates and aluminosilicates it is absolutely necessary to take this circumstance into an account as here we have minerals of completely different chemical function rather than simple saline compounds, crystallochemists believe them to be. ...The possibility to construct the space atomic lattices using the regular mathematical evaluation of X-Ray data — is the supreme achievement from chemical mineralogy. This enabled it to move this part of the science forward, as the latter was weakening and developing too slow for the last several decades. ...From such a co-operation with science field, rich in facts but poor in the modern-level ideology, both areas of mineralogy — chemical mineralogy and crystallochemistry — will benefit"* (Vernadsky, Kurbatov, 1937, p. 16).

Chemical approach to mineralogy was natural for V.I. Vernadsky, as he was an excellent chemist himself, more precisely — chemist-mineralogist like J.J. Berzelius and he worked in chemical laboratories together with such prominent Russian chemists-mineralogists as Konstantin Avtonomovich Nenadkevich, Irina Dmitrievna Borneman-Starynkevich and others. But V.I. Vernadsky interpreted "chemical mineralogy" in a greater sense rather than chemists: *"Chemical mineralogy aims for: 1) determination of chemical composition of natural compounds, minerals, 2) reconstruction of conditions of chemical reactions resulted in mineral formation, their genesis and paragenesis, 3) investigation of their alteration in various geospheres — their weathering, metamorphism (biogenic included). Chemical mineralogy is primarily based on chemistry — on synthesis and analysis of minerals, — but at the same time it is based on and is using field observation — determination of paragenesis and studying pseudomorphs. It is necessary to stress on the latter, as the study on pseudomorphs created by scientific observation, is far beyond the limits of modern chemistry, as reactions should be considered, take place within the solid matter, the crystal matter, the space lattices. ...Pseudomorphs play a great role in the study on paragenesis, which is significant for the dynamics of chemical mineral-forming process. Both the study on pseudomorphs and the study on paragenesis are still incomplete. (But) Actually, the study on paragenesis penetrates all the mineralogy. ...The main chemical problem ever existed for all the minerals, ... was the problem of understanding of digits of chemical analysis of minerals. At the beginning, it appeared that the majority of minerals dramatically do not correspond to the stoichiometric ratios of atoms which constitute the natural compound. They correspond, as solutions, to the undetermined compounds of Berthollet[7]. ...Eilhard Mitscherlich[8] mentioned that these undetermined compounds have similar shapes and compounds with analogous shapes are able to crystallise with non- stoichiometric ratios of all or part of atoms. He named this phenomenon as isomorphism — the feature corresponding to atoms and undetermined compounds crystallised — isomorphic mixtures. ...The simple solution was made mach later, at the beginning of the XX century, by Svante Arrhenius[9], who pointed out that isomorphic mixtures are solid solutions, similar to liquid solutions, which comply with the similar laws"* (Vernadsky, Kurbatov, 1937, p. 16—19).

According to these statements V.I. Vernadsky decided to revise existing facts in mineralogy by writing the multi-volume monograph "Experience of descriptive mineralogy" (Vernadsky, 1955; 1959)[10]. In the foreword to the 1st issue of "Experience" he wrote: "*The major aim is to revise the natural chemical compounds of the*

[7] — Claude Louis Berthollet (1748—1822) — French chemist, the founder of the theory of chemical equilibria.
[8] — Eilhard Mitscherlich (1794—1863) — German chemist, professor at Berlin University (since 1821), the founder of the theory of isomorphism and dimorphism.
[9] — Svante August Arrhenius (1859—1927) — Swedish physical chemist, determined dissociation of compounds and ionic composition of diluted solutions, Nobel Prize winner (1903).
[10] — Vladimir I. Vernadsky overestimated his abilities: only two volumes of "Experience of descriptive mineralogy" were published: volume 1 — Native elements, published in 5 editions (1908—1914) and volume 2 — Sulphury and selenite, in 2 editions (1918 and 1922). These editions are the examples of encyclopedic guidebooks and at present, almost after 100 years, are easily read as if were written recently. This definitely indicates that fundamental mineralogical data does not become out of date and can be only supplemented and revised. The further work on addition and continuation of this edition under the title "Minerals of the USSR" was performed by A.E. Fersman. However only two volumes were also prepared: volume 1 — Native elements, volume 2 — Sulphides and sulphosalts (M.-L.: AN USSR. 1940). The further work was interrupted by the Great Patriotic War and later — by death of V.I. Vernadsky and then A.E. Fersman in 1945.

*Earth from the point of view of chemical processes which take place within it. This, by my opinion, is the main task of mineralogy, which is, similar to chemistry, has to study both products of chemical reaction and these very same reaction processes. This view on mineralogy and revision in this respect all the material on mineralogy took place subsequently in the early 1890s, when I gave lectures in mineralogy at the Moscow University"* (Vernadsky, 1955, p. 9).

Such a grand task by means of one even though extraordinary talented and hard-working person, is unlikely to be accomplished. This can be only done by the team of experiences qualified associates, bind together with the common scientific idea, under supervision of competent respected editor or tough administrator. In this case, the attempt to write such a fundamental encyclopaedic work proceeded against private circumstances and political events. Those include the fight against traditional conservatism of colleagues-mineralogists and indolence of regal bureaucrats, who subsidised scientific research; the situation resulted from the First World war, February and October revolutions; the fight with the sudden decease after which Vladimir Ivanovich found himself in Ukraine, in Kiev (where he founded Ukrainian Academy of Science and became its president) and – in Crimea, in circumstances of civil war followed by devastation of the country. At that time he was trying to find new bonds with the new authority and to prove the importance of intensive and comprehensive mineralogical investigations for development of productive industry in the country. He struggled for discovering in Russia own ore deposits, new perspective types of mineral rough, for studying the opportunities given by atomic energy and for including science into intensive socialistic development. And, finally, he stood for mobilisation of all the forces to help the battle-front against perfidious fascist Germany (where Vernadsky in his young years learnt mineralogical science), in circumstances of Great Patriotic War (WWII). In fact, one had to be Vernadsky to be able to make all that was done for the Russian science.

Accelerated pace of the socialistic economy creation demanded the wide-range practical work in searching, prospecting, mining of ores, technologies of their extracting and separation. This resulted in publishing mineralogical hand-books of a different type – less fundamental and detailed but comprehending more mineral species with characteristics of their possible practical application and with description of the profitable deposits in the country. Thus, V.I. Vernadsky in co-operation with S.M. Kurbatov urgently revised and replenished the data of lectures Vernadsky gave at the Moscow University and that were published in 1910–1912; they publish them as a monograph characterising most important groups of minerals: simple oxides and hydroxides, silicates, aluminosilicates and their analogues (Vernadsky, Kurbatov, 1937). And the team of mineralogists of the Lomonosov institute AS USSR translated the revised and replenished text of "Descriptive mineralogy" by Edward Salisbury Dana[11] (Dana, 1937) from English into Russian under edition by Alexander E. Fersman and Olga M. Shubnikova. In the foreword for this translation Fersman wrote: *"Exceptional need for knowledge in mineralogy is obvious in the past several years. Development of mining industry, expansion and application of various mineral ores, involvement in practice both rare metals, rare compounds and various mineral bodies, widening of application of non-metallic ores and new paths of the modern mineral technology – everything demand, first of all, precise knowledge of a substance itself – a mineral, knowledge of its constants, its exact chemical composition and all the features, which can be used as a searching and prospecting markers, or have specific technological value. On the new path of geochemical analysis theoretic concepts in mineralogy has to use precise constants of minerals obtained by laborious work of crystallographers, crystallochemists and mineralogists for the last 200 years long".*

Concluding this part, it would be impossible to ignore the problem of natural forms of silicon and aluminium – the one V.I. Vernadsky was interested all his life long, starting with his Masters dissertation "On sillimanite group and the role of alumina in silicates" (1891) – investigation that resulted in real revolution in mineralogy. Later, Vladimir Ivanovich wrote about his work: *"After experimental studies of disthen andalusite and sillimanite, that were considered to be saline silicates of aluminium, the author did not find any qualities of saline in them, but pronounced features of acidic anhydrides, close to quartz. In the line of comparative analyses ... the author came to conclusion that alumina and silica play the same role in aluminosilicates and that*

[11] – Edward Salisbury Dana (1849–1935) – son of James Dwight Dana (1813–1868), the author of the famous "System of Mineralogy", who continued its publication with supplements and revisions under the title "Texbook of Mineralogy" till the 6th edition, in 1911, with appendix-3 of 1915.

*they both are acidic anhydrides*[12]*. In that case, kaolinite and its analogues are silica-alumina acids and such minerals as feldspars, leucites, zeolites etc. — silica-alumina salines. Made sure experimentally that the concept about all the silicates and aluminosilicates as about silica salines, I determined aluminosilicates and their analogues as silica-alumina and analogues anhydrides... The similar ideas evolved by Swedish chemist and mineralogist Blomstrand*[13] *in the field of compounds of titanium, niobium, heavy metals; he tried to understand chemistry of more mysterious group of minerals* (Vernadsky, Kurbatov, 1937, p. 25—26).

Vladimir I. Vernadsky made a great effort and spent a lot of time for solving the problem of so-called "kaolinite core" which is considered inaccurate at present. Even in 1898—1899 he determined "existence of typical complex $Al_2Si_2O_7$ *(kaolinite core) which remains stable under endless chemical processes, natural or laboratory, sometimes taking place within solid substance. This complex (metanacrite): 1) had to have chemical character of a complex anhydride, i.e.* $Al_2O_3$ *and* $SiO_2$ *had to have similar functions of acidic anhydrides within it and 2) obviously, that within the crystal lattice they had to be distributed equally in regard to the surrounding atoms: Al and Si had to be chemically identical"* (Vernadsky, Kurbatov, 1937, p. 38). Over a period of many years Vernadsky unsuccessfully tried to refine its chemical formula to explain bonding of cations and aqua with Al, via saturated atoms of oxygen and later accepted the hypothesis by Felix Karl Ludwig Machatschki who admitted (in 1928) that *"in some aluminosilicates* $Al_2O_3$ *and* $SiO_2$ *play the same chemical role. Machatschki pointed to the possibility to avoid the problem by admitting exiting the complexes* $(AlO_4)$ *and* $(SiO_4)$*. These complexes occur as tetrahedra with ions Al or Si in the centre and ions of oxygen — in the corners. ... X-ray data show that in these minerals aluminium and silicon are always surrounded with atoms of oxygen, this is the closest atom amongst the others. This results in peculiar frame.*

$Al_2Si_{2+n}O_{7+2n}$ *(where n can be equal to 0).*

*Accepted the hypothesis by Machatschki ideally resulted in understanding of the whole number of cases which could not be interpreted for a long time"* (Vernadsky, Kurbatov, 1937, p. 36), i.e. finally in denial of idea about "kaolinite core".

This is the history. However we should not forget that V.I. Vernadsky was the first who drew attention to the similar chemical functions of Si and Al within the large group of minerals, later determined as *aluminosilicates* which are greatly significant for mineralogy, petrology and geology. These minerals are rock-forming and almost completely form the Earth's crust, i.e. they are the main form of mineral substance within the Earth mineral-forming processes.

## Mineralogy, geochemistry or "geochemical mineralogy"?

So, who was Vladimir I. Vernadsky after all — mineralogist or geochemist? We believe that such a contraposition is absurd — those are the different sides of the same conception, the same science about natural mineral substance. However, some people used to think that Vernadsky "destroyed" Russian mineralogy by modernizing it and replacing it with "new" science — *geochemistry*. It is hardly possible to claim upon Vladimir Ivanovich that our contemporaries are that neglectful to the *"science of science"* about the mineral substance, which gave birth to crystallography, petrology and geochemistry; upon the scientist who brought up mineralogy, who determined its scientific fundaments and put it to the same level with the other natural sciences about Earth and its inhabitants. We investigated earlier what Vladimir I. Vernadsky meant by the term *mineralogy*. And what did he mean by *geochemistry*?

Vladimir I. Vernadsky, obviously, looked wider. He wanted to get to know the rules of conduct of the chemical elements both on Earth and in the Universe — the processes of their origin (by studying radioactivity), dissemination and concentration (by learning about isomorphism and solid solutions formation), re-distribution during mineral-forming processes and later alteration of minerals (by dealing with genetic or *dynamic*, according to Vladimir Ivanovich words, mineralogy).

[12] — The further investigations of the crystal structures of the polymorphs of sillimanite, on the one hand, confirmed the ideas of V.I. Vernadsky and on the other hand, defined them dramatically. In the sillimanite structure in the chains, elongated along the c axis, aluminium occupies $AlO_6$ octahedra and in $AlO_4$ tetrahedra, alternating with $SiO_4$ tetrahedra (formula $Al(AlSiO_5)$). In the andalusite structure, besides the chains of $AlO_6$ octahedra there occur two-dimensional lattices of alternating $SiO_4$ tetrahedra and $AlO_5$ pentaredron (formula $Al_2(SiO_4)O$). In the structure of kyanite (disthen) one half of $AlO_6$ octahedra occupies in the chains elongated parallel to the c axis and another half — in the chains, where $AlO_6$ octahedra alternate with $SiO_4$ tetrahedra (formula $Al_2(SiO_4)O$). The bonds within the $AlO_6$ octahedra — ionic, within $SiO_4$ and $AlO_4$ tetrahedra — covalent (minerals, 1972; 1981). I.e. only in sillimanite Al and Si are acidic anhydrides, whereas in andalusite and disthen the function of Al — is intermediate between acidic anhydride and silicate saline.

[13] — Christian Wilhelm Blomstrand (1826—1897) — Swedish chemist and mineralogist, professor of the University in Lund (since 1862), a member of the Stockholm Academy of science.

The term "geochemistry" was not his "invention". It was applied as the "chemistry of the Earth's crust" at the end of 1830s – beginning of 1840s, by the scientist from Bazel, Christian Friedrich Schönbein. Quoting Schönbein, Vladimir I. Vernadsky reminded: "In 1842 Schönbein wrote: *"Already some time ago I publicly expressed my belief that we have to deal with geochemistry first, before speaking about the real geological science. The latter has to pay the same amount of attention to the chemical nature of masses that conclude our globe and to their origin, as to the relative age of these masses and fossilized plants and animals embedded. It can be confidently affirmed that geologists would not always follow the direction they do at present; for broaden of their science they have to search for the new supplements and then surely would introduce mineralogically chemical element into geology"* (Vernadsky, 1954, p. 20). I.e. Vladimir I. Vernadsky was obviously in accordance with that and interpreted the term *geochemistry* as *mineralogically chemical element*.

It is believed that Vladimir Ivanovich "gave life" to geochemistry in his speech at the opening ceremony of the Geology & mineralogy section at the XII Meeting of Russian naturalists and medical doctors on the 28th December 1909 (Vernadsky, 1910 – according to: Essays..., 1922). For the first time he drew attention to *paragenesis of chemical elements* in the Earth's crust: *"The ideas by de Beaumont[14] on paragenesis of elements as the function of geological history of their distribution and by Crookes[15], as the result of their dissociation – are the base tones of the modern scientific thoughts in this area. ...Ideas in natural history have to constantly grow, to change and to be created; if they would not be continually fed by the new facts, observations, experiments and specific material, then they would decay and alter and this process would finally lead to dull and dead abstraction... the mystics dissimilar to scientific reality"* (Vernadsky, 1922, p. 75–76). Then, citing the works by Johann Friedrich August Breithaupt from Freiberg, Vernadsky wrote: *"Mineral paragenesis, classifying co-existing minerals, inevitably distributes chemical elements those minerals consist of. It systematizes chemical elements of the Earth's crust. For this purpose it is sufficiently to replace "mineral" with its chemical composition"* (Vernadsky, 1922, p. 77). *"Another system was developed much later. ...That second system – about quantitative composition of the Earth's crust and its separate parts – followed two different paths, both fruitful and important. On one hand they chose the most abundant elements, trying to express numerically or orderly their relative quantity in the Erath crust... in 1888, those attempts resulted in the form, convenient for scientific work, by the American Clarke[16] and later were developed by his follower, well-known Norwegian scientist Vogt[17]. ...However, merely quantitative approach of research, usual for precise chemical conclusions, is obviously not sufficient here. ...Because in the Earth's crust the order of numbers, which express distribution of different chemical elements, varies in a huge scale. Some elements are million and billion times much more abundant than the others. ...The usual and rare elements of the Earth's crust are difficult to compare. For the latter elements, the second path was developed. It was about their traces distribution within the minerals and parts of the Earth's crust, about their dissemination within the natural chemical compounds. ...The only possible explanation for the microcosmic dissemination of elements we can find in those minerals which are comparable with solutions. Due to dissemination, chemical elements form extremely diluted solid solutions – and in diluted solutions the substances solved are subject to gas laws"* (Vernadsky, 1922, p. 77–79). I.e. in this very case, geochemical conclusions are to be based on the analysis of the chemical composition of the specific minerals.

*"Mineral paragenesis is most deeply and in full comprehended by the study about isomorphic series. ...Isomorphic series for us is such a series, where similar compounds give isomorphic mixtures, i.e. are able to give mutual solutions in solid state. ...we have reliable basis for studying natural elemental paragenesis in isomorphic series. Due to them, we understand mineral formulae. The reasonable number of natural chemical compounds enables to apply*

[14] – Jean-Baptiste Élie de Beaumont (1798–1874) – French geologist, a member of Paris Academy of science (since 1835) and its permanent secretary (since 1856), professor of École des Mines (in 1829) and Collège de France (in 1832).
[15] – William Crookes (1832–1919) – English physicist and chemist, a member and a chairman of The Royal Society of London, introduced spectral analysis in science, developed radiometer, discovered thallium.
[16] – Frank Wigglesworth Clarke (1847–1931) – the chief chemist of the Geological survey of the USA (since 1883), all his life was interested in geological problems, summarized and revised an enormous data on the content of chemical elements in the Earth's crust in the book Data of geochemistry (1908). The book was published 5 times (the ast one in 1924), one of the founders of geochemistry, professor of the University of Cincinnati (1874–1883), a member of the National Academy in Washington (since 1911).
[17] – Johan Herman Lie Vogt (1858–1932) – Norwegian petrographer and geologist, the foreign correspondence member of the Imperial Saint-Petersburg Academy of science (since 1912), professor of metallurgy at the University of Christiania (at present – Oslo) (1886–1903), professor of mineralogy and geology at the Norwegian technical high school of Trondheim (1912–1928).

*the method of isomorphic series, which is awkward and inconvenient in chemistry. ...In contrast of chemical series, we would name (them) natural isomorphic series. It is extremely typical that such series are changeable due to not only the type of chemical compound itself, but to the external conditions of its formation. Isomorphic series expresses the quality of specific compounds to form solid solutions of a certain type, in the Earth conditions. Observation reveals that the isomorphic series traverse and alter under impact of temperature and pressure changes. Chemical element which is contained by one isomorphic series at a certain temperature and pressure, is not contained by it at their changed rate, but is contained by another series. At the same time, some elements which are included in some isomorphic series, cannot be included in any isomorphic series at another temperatures and pressures and become the lonely outcasts"* (Vernadsky, 1922, p. 80–83).

*"Thus, the isomorphic series demands the following conditions: partially 1) geological and genetic, partially 2) physical and chemical. The latter can obviously be dependent on the former ones. Geological reasons are clear and can be traced in each separate case. ...However, sometimes the stronger influence would be not from chemical or physical properties, far from isomorphic series itself, but the very ability of the elements to make isomorphic series, i.e. – coincidence of the stability fields within the same crystal classes for the similar compounds"* (Vernadsky, 1922, p. 87).

Later, looking back at the path of geochemistry in our country, Vladimir I. Vernadsky wrote: *"The concept of geochemistry as the science about the history of the Earth atoms appeared on the basis of new atomistic ideas, new chemistry and physics, in close relationship with that specific idea about mineralogy which was accepted in the Moscow University in 1890–1911. Teaching and studying mineralogy were presented with priority of mineral history, genesis and alteration; which were normally moved to the background in the high school. In such a course of mineralogy, geochemical problems appeared to be in a higher scale level that in usual university courses of inorganic chemistry. Continually, the work at the Mineral cabinet of the Moscow University and later – Mineralogical museum of Academy of Science, became more and more geochemical. The name, given by Clarke, found the prepared contents and fertile grounds, but different from his ones"* (Vernadsky, 1954, p. 28).

All cited above clearly demonstrate that *geochemistry* – is the same *mineralogy*, but one might say, the *"higher one"* and Vernadsky's mineralogy – is mineralogy, transformed from purely descriptive and contemplative into the natural historical science, based on precise scientific methods of research. Vladimir Ivanovich introduced in it methods and methodology of both chemistry and geology; in this form it can be characterized as *geochemical mineralogy*. I.e. *geochemistry* and *geochemical mineralogy* are actually synonyms. At Vernadsky's times there was neither complete structural analysis nor modern spectroscopy – i.e. methods of research of a mineral as both a natural chemical compound and a natural physical body. Otherwise, there might appear another term – not geochemistry, but something more precise and broad, for example, "geochemphysics" or "geophyschemistry".

Concerning the tasks of mineralogy in our country, Vladimir I. Vernadsky wrote: *"In the thousand-years-long history of mineralogy, the understanding of its contents changed dramatically. ...The new content was included in the old word. This content is agile; it changes and transforms with time"* (Vernadsky, 1928, p. 21). And this is true. When characterizing modern mineral science, it is important to say, that it has experienced rather glorious but difficult way of development: once had involved the methods of structural analysis, it transformed from chemical mineralogy into crystallochemistry; on the basis of physical chemistry, thermodynamics, physical-chemical experiment and detailed natural observations – into genetic and regional-genetic mineralogy.

## The hard times of mineralogy

All the above said demonstrates the huge role of Vladimir I. Vernadsky – as the reformer of the Russian and the world mineralogy, who showed its first-rate value among the other natural historical Earth sciences and who presented the actual tasks for mineralogy in our country and then successfully solved them in cooperation with the group of his followers. But the fortune of Russian mineralogy was sometimes tragic, which cannot be easily explained, yet being highly valued. It appears that in Russian and the world scientific society there existed forces which disagree with such progressive evolution of mineralogy and its enhancement among the other geological and mineralogical sciences. We believe it would be wrong to keep science about these conditions, which became public from the correspondence of V.I. Vernadsky and A.E. Fersman (Letters..., 1985).

In 1922 the physics-mathematical faculty of the Moscow University gave birth to 12 scientific research institutes, amongst which there were institute of geology (director — A.P. Pavlov) and institute of mineralogy and petrography, supervised by Ya.V. Samoylov — the follower of V.I. Vernadsky. However, they existed only until 1930, when, after reorganization of Moscow State University, geological, mineralogical and some other sciences were excluded from the University[18].

On the 10th January 1936, V.I. Vernadsky wrote to A.E. Fersman: *"Had an appointment with Bauman[19] and there I raised the question about mineralogy in our high school and about rehabilitation of mineralogy and geology departments to the Moscow University. Bauman took effort immediately and insists in urgent solution. Already on the 8th, when I was at Radium institute meeting Gabidulin, I met there also the rector of the Moscow University[20] and talked to him. You and I have to prepare short applications. I will do it tomorrow or the day after"* (Letters..., 1985, № 141, p.174).

In the letter from the 1st February 1936 Vladimir I. Vernadsky wrote about it again: *"I believe that I wrote to you that spoke to Bauman about returning mineralogy to the Moscow University. It looks like the case has moved forward. But, obviously, they are waiting for the determined arrangements from above"* (Letters..., 1985, № 142, p. 177).

And in the letter from the 13th May 1936 Vladimir I. Vernadsky was already worried about the future of mineralogy in the Academy: *"I strongly believe that you can set scientific work in mineralogy on the proper level — there is a huge work and long life in front of you. You are very, very young man, comparing to me. And it is you who only can make it: you are the head of the Lomonosov institute, where your scientific leadership is necessary and where you — and only you — can make it — can change alien to science environment that appeared there in times of your absence now and before. Now you have a giant work to do at the Academy, but the most important — the Lomonosov institute"*[21] (Letters..., 1985, № 143, p. 178).

The letter from the 24th September 1938 is already official, as if it was not a correspondence between friends, recognized world leaders, mineralogists, who did a lot for development of the mineral science in our country:

*"Dear Alexander Yevgenyevich,*

*I ask you to discuss the problem of teaching mineralogy and geochemistry in the high school of our Union and scientific work in the same disciplines in our Academy, at the Department. Due to the reconstruction of the Academy, the situation with the scientific work can extremely retrogress in these disciplines. For more than ten years in our country the question about the state of mineralogy is on the agenda. The first All-Union conference on mineralogy in 1927[22] stressed on the hard situation with teaching and scientific work on mineralogy in our country. In 1930 the Council of People's Commissars had ceased teaching and scientific work in mineralogy and all geological sciences in the Moscow University, where they were at the high level. In 1937, the Second mineralogical meeting appealed to the government again, indicating the abnormality of the situation and damage to the country. All my attempts to make the situation better, via the Committee of the high school and media, were not successful[23]. Now the situation becomes even worse, as the scientific work in the Academy does so.*

*But in the meantime, the need of life demands broad development of these areas of knowledge. Their theoretical and practical application becomes more valuable... Now we need definite arrangements for enhancement of the downward scientific work on these disciplines at the Academy's Geological institute. The situation is that among the directorate staff there is no acknowledgement to these disciplines. For the plan of the 1939 — the prospecting map — the only issue is geology. However, in fact, geochemistry and mineralogy must be equal to geol-*

[18] — Department of mineralogy at the MSU was reestablished only in 1944, at the Geological-soil faculty.
[19] — K rlis (Bauman) Baumanis (1892—1937) since 1934 till his arrest and execution in 1937 was the head of the science department (est. in 1934) at the Central committee of the Bolshevik's party.
[20] — Mathematician, professor A.S. Butyagin was the director since 1934 till 1939 and rector of the MSU — since 1939 till 1943.
[21] — Lomonosov institute of geochemistry, crystallography and mineralogy (LIGEM) under leadership of A.E. Fersman, was established in 1932 by integration of Geochemical and Mineralogical institutes and Mineralogical museum of Academy of science in Leningrad. In 1934 it was moved, along with the Academy, to Moscow and in 1937 was interposed into the Institute of Geological Sciences (IGN AN USSR).
[22] — The conference took place from the 1st till the 6th January 1927 in Leningrad by the initiative of the group of the Leningrad mineralogists, who worked in the Academy of science and the Mining institute. In its work there participated president of the AN USSR A.P. Karpinskiy (chairman), academicians V.I. Vernadsky, A.E. Fersman, F.Yu. Levinson-Lessing, N.S. Kurnakov and the others. A.E. Fersman, in his talk "Mineralogy of the USSR and adjacent countries" indicated the need of the collective work of mineralogists to be resulted in the complete mineralogical description of all the territories of our country within the 10 years.
[23] — The second mineralogical meeting, which took place in Moscow on the 14th—18th of May 1937, was prepared by the Organizing bureau under management by V.I. Vernadsky. But Vladimir Ivanovich did not take part in it due to his illness. P.P. Pilipenko gave a talk "Mineralogy in the high and high-technical schools" about the wrong situation around mineralogical sciences in the high school.

*ogy. As a result, all the problematic seems wrong to me. The prospecting map can be created on the basis of 3 sciences: geochemistry, geology and mineralogy. As to my knowledge, the attempt in the incomparably lower scale – the map of Switzerland by professor Niggli*[24] *– was made by mineralogist. Essentially, geochemistry must occupy the eminent place. All the work of the American mining prospecting, in contrary to ours, is based on the mineralogical-geological fundament. The plan of Geological institute is based only on geological fundament. I believe, that at present in Geological institute scientific work in geochemistry is not properly set and that it is not all right as good young mineralogists (Labuntsov, for example) are moving away from it. The situation is getting more complex by creating two new departments (Geological and Chemical). Geochemistry is the chemical science by its major methodology and which is the reason of its weak position at the Geological institute, where chemical science is on the low level. We have to reconsider now such disciplines as geochemistry and geophysics at the Academy of science. They cannot belong to the Geological department. Geochemistry in a great measure was created in our country, but now we have no place for its forceful development, despite its rising application value.*

*The situation looks critical to me, it demands fundamental solution. Presidium of Geological institute is not scientifically authoritative enough, as the prominent science academician Arkhangelskiy, its chairman, does not participate in it for many months and was not replaced. More than that, I reckon that the program of Geological institute cannot be approved without preliminary coordination with scientific work of the People's commissariat on the heavy industry.*

*Concluding all presented above, I ask you to organize the temporary Commission at the Department, for discussion the problems of teaching and scientific work on mineralogy and geochemistry in our country and at the Academy in particular. I see huge possibilities around, the new generation of mineralogists, which are unable to complete their scientific education and to apply their energy to scientific work. We have to hurry, otherwise life could lose them"* (Letters..., 1985, № 156, p. 190–192).

The same situation with mineralogy was in the foreign countries. In the letters to Alexander E. Fersman from Paris (1923–1924) where Vladimir Ivanovich was sent to give lectures on geochemistry, he wrote: *"At present, the center of scientific work in our area – definitely moves to America and the most interesting publications – American ones. Comparing to that, the European literature in this area is moved to background more and more. In France there are not enough people involved in mineralogy. Departments of all the universities are occupied with crystallographers and only Georges Friedel from Strassbourgh is less strange to mineralogy. Here, Mauguin and Walletan are both crystallographers"* (Letters..., 1985, № 92, p. 107). *"In Germany, I think, it is specifically bad, especially with mineralogy. The most prominent one was Groth; Hecke, Tschermak, Niggli – are not German. And now, as it was before the war, they have no outstanding mineralogists. But in other areas they have physicists, chemists, mathematicians"* (Letters..., 1985, № 97, p. 117).

A similar pattern holds for mineralogy in our country at present. Mineralogical theme is actually excluded from the *priority* research mainstream of the Russian academy of science (see Decree of the Presidium RAS from 1st July 2003 № 233 as well as the "Plans for Fundamental Research Russian Academy of Sciences for the periods 2006–2010 and 2011–2025"). In the last part the word "mineral" exists only in one *program* № 67 as: *"Fundamental problems of development of lithogenic, magmatic, metamorphic and mineral-forming systems"*. Nice but difficult to understand – as if lithogenic, magmatic, metamorphic systems are not the mineral-forming ones? In the reviewed "VAK" magazine *"Proceedings of Academy of science"* you will find neither section "mineralogy", nor "crystallography" (everything was included into "geochemistry"). Good news still that geologist are still awarded with the philosophy doctor degree of *geological-mineralogical* (and not *geochemical*) sciences, reminding with that that without the knowledge in mineralogy they cannot be the professionals in geology. Of course, at present there are no such mental giants like Vladimir I. Vernadsky or Alexander E. Fersman, but mineralogy still exists and successfully develops, taking in methods and achievements of chemistry and physics, as Vladimir Ivanovich predicted long ago.

## Vladimir I. Vernadsky and the present times

Vladimir I. Vernadsky was not only the first-rate scientists but also the uncompromising social, governmental and political activist,

[24] – Paul Niggli (1888–1953) – Swiss mineralogist, petrographer and geochemist, professor of the University of Leipzig (1915–1918), Tübingen (1918-1920) and Zürich (since 1920) and Eidgenössische Technische Hochschule (since 1920), the foreign correspondence member of the Academy of science of the USSR (since 1924).

keenly reacting to all the events in Russia and in the world; at the same time he was curating huge scientific and scientific-organizing work of a great value.

We would not recall about his emphatic retirement from the Moscow University with his students and followers: A.E. Fersman, V.V. Kandeev, G.I. Kasperovich, Ya.V. Samoylov, V.M. Tsebrikov and 126 other lecturers in protest of arrangements of the Minister of education L.A. Kasso, who broke the University's autonomy, gave it to the police arbitrariness and who discharged rector A.A. Manuylov, his assistant M.A. Menzibir and deputy rector P.A.Minakov, disagreed with that. In the same 1911 in respect with the 200th anniversary of M.V. Lomonosov's birth, Vladimir I. Vernadsky actively participated in application of the Academy to the Tsar's government to organize the Lomonosov institute[25] on the base of chemical and mineralogical laboratories and physical cabinet of the Mineralogical museum (Vernadsky, 1911). During the World War I and after the October Revolution he organized KEPS and SOPS — Commission and Counsel on investigation of the natural productive forces in Russia; he actively works at the discovering Russian own ore deposits and strategically important ores, which are necessary in war times and the further economic blockade from the side of imperialistic countries. Being involved in a research of uranium minerals and radioactivity, he organized Radium institute in Petrograd, on the base of the respective laboratory of the Mineralogical museum. Later, he insistently recommended the Soviet government to investigate in the area of nuclear energy. During the Civil war he happened to be in Ukraine, where he founded the Ukrainian Academy of science and became its president. When directing the Mineralogical museums in Moscow and St.-Petersburg-(Petrograd), he organized analytical laboratories within them, which later became scientific-research institutes etc. It is impossible to list everything. Shortly before his death in 1943 he was awarded with the Stalin's Prize of the first rank, for his scientific and organization works; this, in some extent, demonstrates recognition of his contribution in foundation and development of the Russian mineral science by the Soviet government.

We, mineralogists, do not need any proofs. In Russian and world science there hard to find a person which is comparable with Vladimir Ivanovich Vernadsky by his authority, erudition, scientific and organizing deeds, contribution in science.

But how do we respect the heritage of this ingenious scientist 100 years later? Differently, indeed. There are researchers which fairly show onto some mistakes and out-of-date solutions and ideas. And how is without it? Although Vladimir I. Vernadsky undoubtedly was far ahead of his time, he could not surpass future, eternity. Science (and also mineralogical) rapidly moves forward, despite obstacles of life, that is always full of contradiction of social-economical formations, countries, people, religions, all that interests and well-being of elite and leaders. Science has more noble and generous tasks and targets, including acquirement the knowledge about humanity, about world, about the planet Earth — its structure, composition, processes which take place on it, in it and in its far past, geological history. In this respect, Vladimir I. Vernadsky was the brightest person, the fighter for the power of the world science and the world human fairness. He was standing above strictly government, strictly political party, strictly clan interests; he was the Man of the World.

His ideas are actual at present as in the past, as they were founded on the basis of scientific methodology, which was developed alongside with the total progress of the methods of research and knowledge, in fight with conservatism, admiration of authorities and limitation of scientific schools, for omnipotence and power of objective scientific facts.

What is the situation in our mineralogy at present? Even among the prominent scientists there is an opinion that mineralogists should be involved only in mineral diagnosing, for the other sciences studying Earth, for those scientists who produce global ideas about the genesis of rocks, minerals and ore deposits. The top achievement of mineralogist should be precise diagnosing, description of the mineral phases and discovery of the new mineral species and these are exactly what is supported by various grants, projects, collector's and amateur's interest (rather than genetic mineralogy).

Vladimir I. Vernadsky taught and appealed to another idea. And, in particular, the idea that mineral, as a major form of mineral substance in nature, must be in the center of all the Earth sciences. And that on the fundament of the detailed chemical, physical, structural investigation of minerals, natural observations and physical-chemical experiments mineralogists

[25] — In 1912 the Tsar's government formally agreed with the organizing Lomonosov institute, but the Academy did not receive neither funds, nor piece of land for its construction. It did not find any funding for it in 1912—1918 in respond to the second application of the Academy. Lomonosov institute was established only during Soviet times, but did not exist for a long period.

can and have to obtain the most valuable information about the composition, structure and features of the natural chemical compounds and can use this information in solution of genetic and applied problems. Something was achieved in this direction: genetic, regional, experimental, applied and technological mineralogy are developing. Those are the powerful arsenal of mineralogy branches which are able to provide with the detailed mineralogical description of geological objects, to reveal mineralogical indicators for search and prospecting of the ore deposits, to be the basis for choosing the method of mining, technology of processing and extraction of the ore components and finally to use structure and features of number of minerals as new and innovative materials. However, one has to have the will and skill to use it.

## Instead of conclusion

More than a century ago, academician Vladimir Ivanovich Vernadsky (1863–1945) – the greatest Russian naturalist of the XIX–XX, whose 150th anniversary we celebrated this year, achieved a scientific feat – he got over misunderstanding and conservatism of the number of the "office" scientists and authorities. Resolutely and constituently, he introduce practiced new trends of the world science appeared at that time into practice of mineralogical research and teaching mineralogy at the department he was leading at the Moscow University. For a relatively short time he created brilliant Russian school of mineralogists, equipped it with scientific-research institutes and organized excellent mineralogical museums in Moscow and Petersburg. Russia is lucky to have such a Scientist, Patriot and a Man, who was able to lead mineralogy onto the first positions in the world. According to A.E. Fersman: "*There is no doubt that Vladimir Ivanovich – is the largest and the most original researcher of live and dead nature, the creator of new scientific trends, the reformer and the founder of Russian mineralogy and the world geochemistry*" (Fersman, 1946, p. 788). He "*has not only remarkable organizing talent, but also deep knowledge in the number of science areas: mineralogy, geochemistry, biogeochemistry, biology, soil science, geology, chemistry, physics, crystallography, energetics, radiogeology, radiography, hydrology, cartography, history of science, philosophy etc. Such diversity of creative thinking was combined with the rarest depth of analysis*" (Fersman, 1946, p. 789).

Unfortunately, the uncommon talent of naturalist and tutor Vladimir I. Vernadsky to predict and to understand trends of the world science, the mainstream tasks and contradictions in progress of the human civilization on Earth, deepest patriotism, the need in serving people and his fatherland, Russian science, the ability to understand the leading value of mineralogy within the Earth sciences, its role in economics, ecology, culture and human history – all these often run against one's indifference, misunderstanding and maybe envy. But Vladimir Ivanovich was unselfishly serving the science, believed in progress and power of mineralogical science, despite all the obstacles made and taught his followers and those who wanted to be one of them. Besides, he studied in detail the problem he began with, in historical aspect: what has been done in this direction by his predecessors. Alexander E. Fersman indicated: "*Vladimir Ivanovich always began to study every phenomenon with precise historical analysis. And regardless of the beginning of his treatise or description, it was always preceded with the history of a problem. Vladimir Ivanovich always required deep description of the history, from us, his students; and he made it not formally but practically, by teaching us to understand the way of a thought and the history of its development*" (Fersman, 1946, p. 790).

"*In one of the letters from Italy, Vladimir Ivanovich wrote about the role of museum in the history of science. Museums, according to his opinion, had an exceptional value in development of natural sciences and culture in general... he told: "We, naturalists, have to learn from historians the deep historical methods of understanding of the mankind past. Using these methods we can become the historians of nature*" (Fersman, 1946, p. 790–791).

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