

VLADIMIR VERNADSKY'S IDEAS AND CONTEMPORARY SCIENCE

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In the constellation of eminent scientists of the 20th century you will hardly find another one who stood at the cradle of so many new disciplines and promoted the development of so many varied branches of science. Genetic mineralogy, geochemistry and biogeochemistry, radiogeology, the theories of living matter, the biosphere and its transformation into the noösphere—this is by far an incomplete list of fundamental disciplines that were founded by Vladimir Vernadsky and made rapid progress in the current century. He made great contributions to soil science, biology, geology, radiochemistry, space chemistry and other fields of knowledge. Vladimir Vernadsky's scientific views and fundamental generalizations were well ahead of the epoch in which he lived and were often underestimated by his contemporaries.

The deteriorating global ecological situation as a consequence of the rapid pace of scientific and technological progress, and urgent tasks of nature conservation have commanded the attention of the scientific community and public opinion to problems of the biosphere and to the personality of Vladimir Vernadsky, the founder of the theory dealing with it. According to Vernadsky, the biosphere is a "sheath of life—the domain where living matter exists." He was the first to demonstrate that the main role in geological and geochemical processes belonged not to individual organisms, but to their totality which the scientist called "living matter"—the most potent geological force of the biosphere.

The theory of the biosphere was the core of Vladimir Vernadsky's scientific endeavors. An exclusive place in the study of laws of the biosphere and the geochemical activity of living matter belongs to biogeochemistry, or "chemistry of the biogenic processes" as the scientist defined it. In founding biogeochemistry as a science studying the effect of life on the history of atoms of the Earth's crust, Vernadsky logically extended the views of geochemistry which he described as the science of the 20th century. [He linked the emergence of both geochemistry and biogeochemistry with the revolution in physics at the threshold of the 20th century—a series of discoveries and studies that conclusively showed the unity of the material world, from the atom to the cosmos.

Vladimir Vernadsky first occupied himself with problems of biogeochemistry in 1916 and dealt with them till the end of his life. He formulated the basic laws of that new branch of science in six theses found in the book "Problems of Biogeochemistry" (1934-1944), in many papers of different years that eventually made up the volume "Theses on Geochemistry" (re-printed four times in Russian and French in 1924-1934), and in his unfinished monograph "The Chemical Composition of the Biosphere of the Earth and its Surroundings", to which he dedicated the last years of his life and regarded it as his most important scientific paper.

The scientist was the first to demonstrate that living matter was the carrier of free energy in geochemical processes occurring in the biosphere and an active element of the latter. He defined the geochemical functions of life in the biosphere, notably gaseous, concentrative, oxidation-reduction and biochemical functions. Taken together, they determine principal chemical manifestations of all living matter in the biosphere and support the existence of the biosphere in all epochs of the geological history of the Earth. With the appearance of man they were complemented by the biochemical function of *Homo sapiens*—a potent geological force changing the image of the Earth.

"The biosphere is eternal, geologically speaking." This conclusion made by Vladimir Vernadsky is of paramount importance for answering the question when life on Earth emerged. In Vernadsky's time it was believed that life on this planet had existed for at least two billion years. Modern studies of sedimentary rocks found in the Earth's crust, which the scientist described as the "zone of the former biospheres", indicate that organic life has existed for about four billion years. For instance, [according to the conclusion of the German researcher H. Pflug, rocks aged four billion years contain structured organic matter, and acceptable conditions for life on Earth appeared 4.2 to 4.3 billion years ago, that is, in a relatively short span after the emergence of the planet Earth in the Solar system (4.55 billion years ago).

We are witnessing the development of biogeochemistry in many directions originally charted by Vernadsky and the emergence of such subspecialties as geochemical ecology, biochemistry of the ocean and biochemistry of soil. Biogeochemistry of the technogenesis is acquiring more and more importance in view of the continuous economic activity of man. At the threshold of the 1920s Vernadsky formulated the idea that living matter determined the future of chemical elements in the crust of the Earth. In this, as it was learnt later, he was right. He revealed an exceptionally important role of living matter in the cycling of chemical elements on the surface of the Earth and in the biosphere. With time it became known as the "Vernadsky law".

Geochemical ecology emerged at the junction of two branches of science: biogeochemistry of chemical elements and ecology. It deals with the effect of the composition of the geochemical environment on the evolution and functioning of living organisms. The principles of biogeochemical zoning made it possible to determine provinces and territories where endemic diseases of plants, animals and man were possible due to a shortage or excess of certain microelements (iodine, cobalt, manganese, strontium, molybdenum, zinc and others). One example is the disorder of the thyroid gland caused by the shortage of iodine in potable water—a disorder which is known to lead to the formation of endemic goiter. The presence of certain elements in the chemical composition of plants due to the geochemical environment underlie the geochemical method of prospecting for rare and scattered elements—a method widely used in the search for minerals. Plants that indicate the presence of or concentrate certain chemical elements help geologists determine the outlines of an ore body and areas of scattering.

The findings of modern science conclusively corroborated Vernadsky's assumption regarding a close relationship between the mineralogical composition of the Earth's crust and living matter. The formation of most important types of rock, notably carbonate, siliceous, phosphoric, ferruginous, manganese (including iron-manganese concretions), and aluminous rock (bauxites), is explained by the manifestation of certain biochemical functions of life and its effect on the accumulation of sediments in lakes, marshes, seas and oceans.

Modern soil science links the formation of soil with the biogenic transformation of rock into soil. "All processes in soil," Vladimir Vernadsky wrote back in 1919, "occur with the participation of living matter or products of its change." The soil mantle ensures the existence of green plants. Their energy and biomass are used by animals and microorganisms participating in the biological cycling of matter in the biosphere.

Vladimir Vernadsky is by right considered to be the founder of a trend in biogeochemistry dealing with the Ocean. He wrote that the Ocean "is permeated by living matter." Studies conducted by Soviet scientists show that the geochemistry of sea water, suspensions and bottom sediments is determined on the whole not simply by the mechanical or chemical differentiation of initial matter, but is governed by the laws of the biodifferentiation.

In his biogeochemical research Vladimir Vernadsky devoted special attention to carbon as the chemical element most typical of living matter. The scientist's fundamentally important assumption that the departure of carbon from the life cycle and its burial in sediments determines the possibility of existence of adequate masses of free oxygen in the biosphere, was vividly corroborated by studies carried out later. His conclusion that combustible minerals, oil among them, "are born in their constituents already in organisms" was well ahead of the level of development achieved by biology and chemistry in Vernadsky's time.

He predicted a revolution in biology. In his 1931 paper "The study of the Phenomena of Life and New Physics" he wrote: "the revolution in physics in the 20th century is bringing to the fore as one of the tasks of scientific thought a review of the fundamental ideas of biology." Indeed, the revolution in biology brought about by the switch to the molecular level in the study of all living things and the emergence of molecular (physicochemical) biology in the 1950s confirmed his idea that "science is all-embracing and all the domains under its study are very closely interconnected."

Research in earth sciences at the molecular level elevated paleobiochemistry, geochemistry, biogeochemistry and paleontology to a qualitatively new level of development. It became possible to consider biogeochemical processes at the level of constituents and structures making up living organisms, that is, to switch to molecular biogeochemistry which deals with the geochemical history of biomolecules commencing in living matter and continuing in the geological formations of various strata. The theory of molecular biogeochemistry and its role in studying the genesis of combustible minerals was developed by Soviet scientists.

Researchers from different countries have determined that a major part of oil compounds is represented by biomolecules that remained intact or underwent various degrees of transformation. The information retained by them makes it possible to trace the pre-history of oil

from the biomolecules formed by algae, highly organized plants and other organisms of the paleobiocenosis—the source of organic matter of future petroliferous deposits—to the processes of formation of the substance of oil in sedimentary rocks, processes eventually leading to the appearance of that unique combustible mineral. Molecular biogeochemistry provides qualitatively new proofs of the genesis of oil, creating a molecular basis for the biogeochemical reconstruction of the processes and history of oil formation in specific geological conditions.

As predicted by Vladimir Vernadsky, the ideas of biogeochemistry now have a bearing on different sciences from astrophysics through earth sciences to biology, agriculture, medicine and nature conservation. Over the seven decades of its development biogeochemistry has acquired paramount importance (both from the standpoint of science and world outlook) for understanding the essence and origins of life, the relationship between organisms and the environment, and the geological role of living matter, for appraising man's impact on nature and its possible aftermath. As for biogeochemistry's developing in the spirit of Vladimir Vernadsky's ideas time is evidently in store for it. This is particularly true of future biochemistry that will deal with the noösphere—the sphere of the human intellect—which mankind is entering. "The thinking and working man is a measure of everything," Vladimir Vernadsky wrote, "He is a great planetary phenomenon."

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