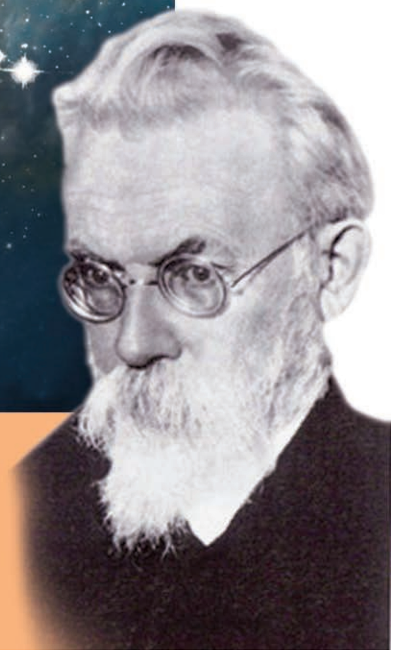
Milky Way galaxy



V.I. Vernadsky by A.E. Yeletsky, 1949.

150 Years of Vernadsky

In celebration of the year of Vladimir Ivanovich Vernadsky, it is crucial to further his hypothesis on the nature of progress and direction in evolution, for both its scientific subject, and even more for the implications of that scientific principle for society today.

V.I. Vernadsky and The Contemporary World

by Academician Erik Galimov

Since 1992, Academician Erik Galimov has been the director of the Vernadsky Institute of Geochemistry and Analytical Chemistry, of the Russian Academy of Sciences. The Institute was created by Vernadsky, and named for him after his death. Galimov is the editor of the journal Geokhimia [Geochemistry International]. *He has contributed to the fundamental understanding of isotope fractionation, the science and resources of the Moon, Mars exploration, and in 2012, Galimov's most recent book, written with co-author Anton Krivtsov,* Origin of the Moon: New Concept: Geochemistry and Dynamics, *was published by De Gruyter, Inc. Academician Galimov is a Member of the Presidium of the Russian Academy of Sciences.*

This article is adapted from Academician Galimov's presentation at the meeting of the Presidium of the Russian Academy of Sciences in 2003, on the occasion of Vernadsky's 140th anniversary. It has been translated from the Russian by William Jones.

This year we are marking the 140th anniversary of the birth of V.I.Vernadsky. Normally, such a jubilee would deal with a personality whose achievements and activity occurred in a fairly distant past. The contemporaries of V.I. Vernadsky, born around the same time, were physicists Marie Skłodowska-Curie and Max Planck, chemist Svante Arrhenius, and geologist Jakob Johannes Sederholm. We recognize and honor them in their role in the history of science. But when we speak of Vernadsky, we are not speaking about history, but almost always about problems of the present. From where derives that surprising modernity of V. I. Vernadsky?

Vernadsky combined in his person the qualities of researcher and thinker. He held strictly to the facts, demanding experimental or computational verification for every conclusion. He always characterized his generalizations as "empirical." His usual comment was: "We must not exceed the bounds of the known facts." At the same time, generalization was precisely his style. He arranged and combined the facts into the form of conceptions, from which he made forecasts. Therefore, the results of his work were directed toward the future. Thus, our feeling of his modernity.

Very often Vernadsky raised problems which did not seem pressing at the time.

Today, when we work diligently to identify the priorities in science and want to define its development by means of our present logical understanding, it is useful to keep in mind one bit of advice from Vernadsky: "New sciences which are continually being created around us, are created in accordance with their own laws, laws which do not stand in any relation to our will or to our logic. On the contrary, when we examine the process by which any new science comes into being, we see that this process does not correspond with our logic. The course of the history and development of science, the course of the elucidation of scientific truth, does not at all correspond to that which, it would seem, ought to have come about according to our logical understanding."

The major scientific achievements of V.I. Vernadsky are widely known. They were his creation of a body of thought concerning the role of living matter in geological processes, the foundation of modern geochemistry, his teachings on the noösphere, etc., which I will touch upon.

But I would like to begin with an important, although little known area of Vernadsky's scientific thought.

V.I. Vernadsky first began to look at the geology of the Earth as a product of its history as a planet in the Solar System. He said that one could not consider the Earth apart from its relation to the cosmos.

Keep in mind that at that time, geological surveys only encompassed the upper structural layer of the Earth's crust. There were no data regarding the deeper structure of the Earth, the composition of the Earth's mantle, or its core. There were no data regarding the structure of the ocean bottom. Consequently, any approach to a comparative global study of the Earth with other planets of the Solar System was absolutely extraordinary.

In November, 1930, Vernadsky wrote in his diary: "We now see as a clear and practical task of the near future, the capture by man of the Moon and the planets."

Of course, Vernadsky understood that matter from other planets that would be necessary for a comparative analysis would not be in the hands of investigators any time soon. But there were other ways of doing this, namely, through a comprehensive investigation of meteoritic material. Meteorites are fragments of bodies of the Solar System which have fallen to Earth. Vernadsky organized the collection and the classification of meteorites, launching an effort to expand the collections. In the 1920s and 1930s, regular scientific expeditions were conducted to the sites of meteorite impacts. In 1935 a Meteorite Commission was organized, and later, in 1939, it was transformed into the Committee on Meteorites (KMET) under the USSR Academy of Sciences. V.I. Vernadsky became the chairman of the Committee. In 1941 publication of the journal *Meteoritika* began.

Vernadsky placed great importance on the study of the nature of the Tunguska meteorite (1908). He gave his support to organizing an expedition to impact area. This resulted in the collection of extensive factual data. At that

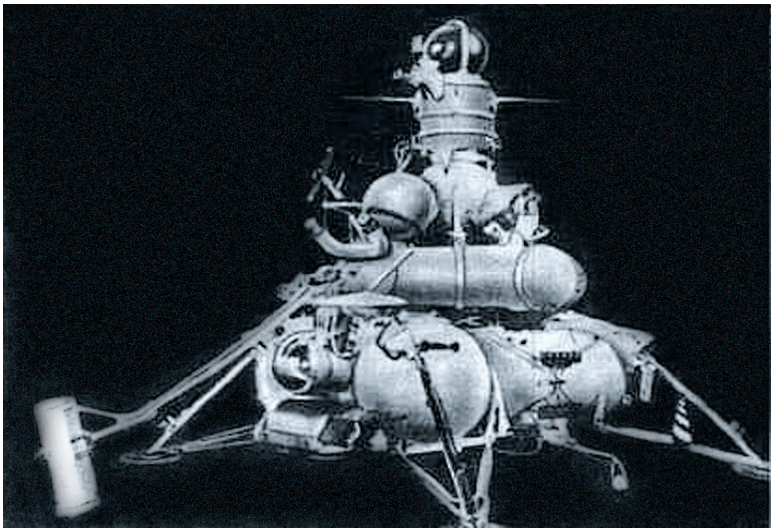
The Museum of Extraterrestrial Material of the Russian Academy of Science.

Vernadsky organized the early investigation of meteoritic material, and in 1939 became chairman of the Committee on Meteorites of the Academy of Sciences. Under the initiative of Academician Galimov, the Laboratory of Meteoritics was formed in 1998. The Laboratory holds the Russian lunar sample collection, and the meteorite collection of the Academy of Sciences. Pictured is part of the collection of the Museum of Extraterrestrial Material in Moscow.

time, Vernadsky gave his interpretation of the event, which is fairly close what we now know. He wrote: "…the mass of matter from space which penetrated the Earth's atmosphere, did not fall to the ground, but left only a residue of matter in the form of very fine dust." Possibly this was a result of "the penetration into the Earth's gravitational field, not of a meteorite, but of a huge cloud, or clouds, of cosmic dust, moving with cosmic speed."

It was only 20 years ago that it became clear, thanks to the discovery of isotopic anomalies, that meteorites contain particles of the pre-solar cosmic dust originating in the vicinity of the Sun. And yet, Vernadsky was already writing about this in the 1930s.

"Cosmic clouds apparently consist of particles, that would appear to be similar to those we find in meteorites… It is quite possible that cosmic clouds are related in some way to comets. In the instances where these clouds fall to the Earth with cosmic speed under the influence of the Earth's gravitational, and possibly even its magnetic field, they can create craters or depressions…"



National Space Science Data Center, Goddard Space Flight Center

Luna 16 was the world's first robotic spacecraft to land on the Moon and return a sample of lunar soil to the Earth. That Soviet mission, in September 1970, followed the Apollo 11 and 12 U.S. manned missions. Luna 16 brought back, in an hermetically sealed container, 101 grams of material collected in the Sea of Fertility, on the Moon.

The idea of the common nature of matter from ordinary chondrites and that of the Earth, was further developed in Russia by a person who continued the work of V.I. Vernadsky, Academician Alexander Pavlovich Vinogradov, who from 1947 led the Vernadsky Institute of Geochemistry and Analytical Chemistry. This idea appeared fruitful, to the greatest degree. It opened the way to an understanding of the nature of the structure of the Earth's geospheres, and to prediction of the composition of the Earth's mantle and core. Later, when we received samples of lunar soil from the Soviet robotic stations Luna-16, Luna-20, and Luna-24, and from the American Apollo missions, it was revealed that the basalts of the Moon just slightly differed from basalts on the Earth, and that the chemical structure of the Moon, as well as the chemical structure of the Earth, can be deduced from the chondrite model.

Vernadsky considered the Earth as being in energetic and meteoritic exchanges with the cosmos and with other bodies of the Solar System, and that geological history ought to be reconstructed with consideration of that factor.

It is interesting that today we are able to find and analyze lunar and Martian fragments which have fallen to Earth. When we talk about the chemical and mineralogical composition of the Martian soil, the question sometimes arises, where did that data come from, as we have not yet been able to bring back soil from the surface of Mars? The fact is that the Earth has received dozens of meteorites, which, from a number of indications, are of Martian origin. This includes the so-called SNC meteorites. They have characteristic correlations of the three isotopes of oxygen, ^{16}O, ^{17}O, ^{18}O which differentiate them both from Earth and from other types of meteorites. In order to definitely determine that they are of Martian origin, we have to bring back to Earth at least one sample from Mars. If it falls into the category of this three-isotope oxygen diagram of the SNC meteorites, then we will be able to consider that we possess matter of Martian origin, in our museum at the Vernadsky Institute of Geochemistry and Analytical Chemistry.

Lunar meteorites have been discovered in Antarctica, which correspond in their composition to samples studied from the lunar surface. Furthermore, it is proposed that we conduct a search on the Moon for ancient samples from Earth. The collision of large meteorites with the Earth's surface could have dislodged chunks of rock and deposited them on the Moon. We know that no rocks more than 4 billion years old have been preserved on Earth. A chronicle of the first 500 million years of the Earth's history has been completely lost. But it is possible that fragments of ancient rock, carrying invaluable information on the early pre-geological history of the Earth, might be found on the Moon.

Also, on Vernadsky's initiative, the first collection and investigation of cosmic dust in the Arctic snows and its maritime sediment was organized.

His idea of studying the Earth as one planet in the Solar System, which at one time may have appeared exotic, is now fully recognized and accepted, and serves as the working concept for international scientific organiza-

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In 1972, Luna 20 returned a second cache of soil from the lunar surface. Pictured here is the sealed container holding the extraterrestrial material, which landed in the snow, waiting to be retrieved.

tions. Obviously, problems concerning the origins of planetary atmospheres, the origins of the Earth's oceans, and the mechanism by which planetary cores are formed, are problems which are impossible to solve simply by focusing on the Earth alone.

This is particularly the case with regard to the problem of the origin of life. After fifty years of the triumphal development of molecular biology, it suddenly became evident that the final word in resolving this issue had to involve biogeochemistry and planetology. The search for forms of life beyond Earth, finding clues pointing to the existence of life now or previously on other planets, is an officially declared goal of the U.S. planetary program. The American program includes an intensive investigation of Mars, providing for the launch of spacecraft every two years

Unfortunately, Russian opportunities in this field are somewhat more modest. An important future mission would be to Phobos, a moon of Mars, in order to bring back soil, investigate its characteristic organic composition, and determine the isotopic components of its oxygen. This would permit us, as was earlier indicated, to draw a decisive conclusion regarding the origin of the SNC meteorites, and would at the same time answer the important question of how Phobos was formed as a Martian moon.

V.I. Vernadsky returned repeatedly to the problem of the origin of life, but approached it very cautiously, since here, as in other areas, there arise a variety of speculation and colliding world views. For some time he supported the panspermia thesis. This was closer than anything to his understanding of life as a cosmic phenomenon, eternal in its existence. Following Vernadsky in a better and more accurate formulation, we ought to speak, not of the "origin of life," but rather of the genesis and evolution of the biosphere.

The conditions, the mechanism, and the time of the genesis of the biosphere on Earth are not dependent upon one's concept of the origin of the phenomenon of life. Nevertheless, it is important to note that V.I. Vernadsky looked at this problem as a cosmic problem, closely linked to an understanding of the mechanism by which the planet was formed. And that is exactly how the problem is posed today.

Regarding the contributions of V.I. Vernadsky to world science, it is of course impossible not to underline once again how he introduced into science an understanding of the role of living matter in geological processes, including on a planetary scale.

The very term "living matter" was unexpected and unfamiliar, and became a subject of debate. Vernadsky wrote in this connection:

> What we study in terms of living matter is not a biological process, but a geochemical one... We need to encompass as completely as possible the matter which is changed by life processes, however accidental this might be from the standpoint of the functions and morphology of a given organism. But we are studying a mass phenomenon, using statistical methods, and thus anything truly accidental is balanced out, and we obtain a representation of the average phenomenon.
>
> If we use the term "living matter" in this sense, reducing it to mass, composition, and energy, we shall see that this term is quite adequate for a whole array of fundamental scientific questions... Living matter, like the biosphere, possesses its own special mode of organization, and may be viewed as a lawfully expressed function of the biosphere.

From the lines quoted above, it is evident that for Vernadsky, life was not only a quantitative factor, but was also important in itself. The tremendous role of life in planetary processes boggles the mind. The factor of life determined the formation of the granite in the Earth's crust, and the oxygen content of the Earth's atmosphere. Life, through photosynthesis and the production of reduced carbon, sets in motion the oxidation-reduction cycle in the Earth's crust. This regulates the global processes of ore-formation. The biosphere itself is not simply the geological envelope, but the receptacle of life. The biosphere refashions the Earth's geology in such a way that it acquires

NASA/JPL-Caltech/University of Arizona

This stunning image of the Martian moon, Phobos, was taken in 2009 by the High Resolution Imaging Science Experiment camera, aboard NASA's Mars Reconnaissance Orbiter. An important mission, Academician Galimov proposes, is to return soil from Phobos, to help determine the origin and the history of Mars, as well as its small moon.

properties which it would not have in the absence of life. Living organisms beget processes which occur with unusually high speed, in unusual directions.

The crowning doctrine of the biosphere, which makes it a genuine philosophical conception, is the concept of the transition of the biosphere into the noösphere. Until the appearance of man, evolution was a disorderly process. With the appearance of mind, a new organizing factor enters the biosphere. The activity of man acquires a geological stature, and is in a position now to direct the evolution of the biosphere, and, if you wish, geological evolution.

This concept of V.I. Vernadsky did not immediately gain attention. Pollution, climate change, and environmental disasters were for some time considered as isolated phenomena unconnected to the results of technogenesis. But with time it became evident that they were related to our entry into the noösphere, with its new and still unknown laws.

We have seen that the Cyclops-like powers, which man has attained, can create not only satisfaction but also concern. But we must say that V.I. Vernadsky viewed the transition from the biosphere to the noösphere optimistically.

These are some of his conclusions.

"The noösphere is a new geological phenomenon on our planet. In it, for the first time, man becomes a large-scale geological force. He can and must rebuild the province of his life by his work and thought, rebuild it radically in comparison with the past. Wider and wider creative possibilities open up before him… We are living in an exceptional time in the history of our biosphere, in the psychozoic era, when a new state of the biosphere is being created—the noösphere, and when the geological role of man begins to predominate in the biosphere and broad horizons for his future development open up… Science is a creation of life. Scientific thought takes from the life around it material from which it adduces scientific truth…This is the fundamental expression of the life of man in his surroundings—in the noösphere. Science is the manifestation in human society of the action of the aggregate of human thought."

Was Vernadsky correct in his optimism? There are also other, pessimistic predictions, which regard the noösphere as the final stage of the development of the biosphere of our planet. Humanly speaking, I would like to believe that V.I. Vernadsky is right.

Vernadsky was a philosopher of science. That which he called an empirical generalization, was in fact a philosophical comprehension of the known facts.

The philosopher-scientist to a much greater degree exerts an influence on the development of his own nation than the specialist-scientist. In his understanding and exposition of them, scientific facts acquire a meaning transcending the bounds of the particular sphere of knowledge. They become intertwined with the social and historical background.

The cultural, social, and historical context is always of a national character. From Vernadsky himself we have the words: "Scientific achievements may be universally binding and unifying for everyone. But philosophical ones? I don't think so."

It is possible that this explains why V.I. Vernadsky is relatively little known in the West, where scientific schools are generally focused on more pragmatic and concrete approaches. The world of Western science grasps work done in the East or in Russia only when it contains specific facts, calculations, etc., having, in Vernadsky's words, the character of being "universally binding." But with regard to generalization, to philosophical interpretation of facts, or even simply to the interpretation of those facts, they trust more their own judgment.

There is no need, however, for us to seek an international certificate of recognition for our great compatriots. We must be able to evaluate ourselves the contributions of those who formed our world view, our national character, and determined our style in science and culture.