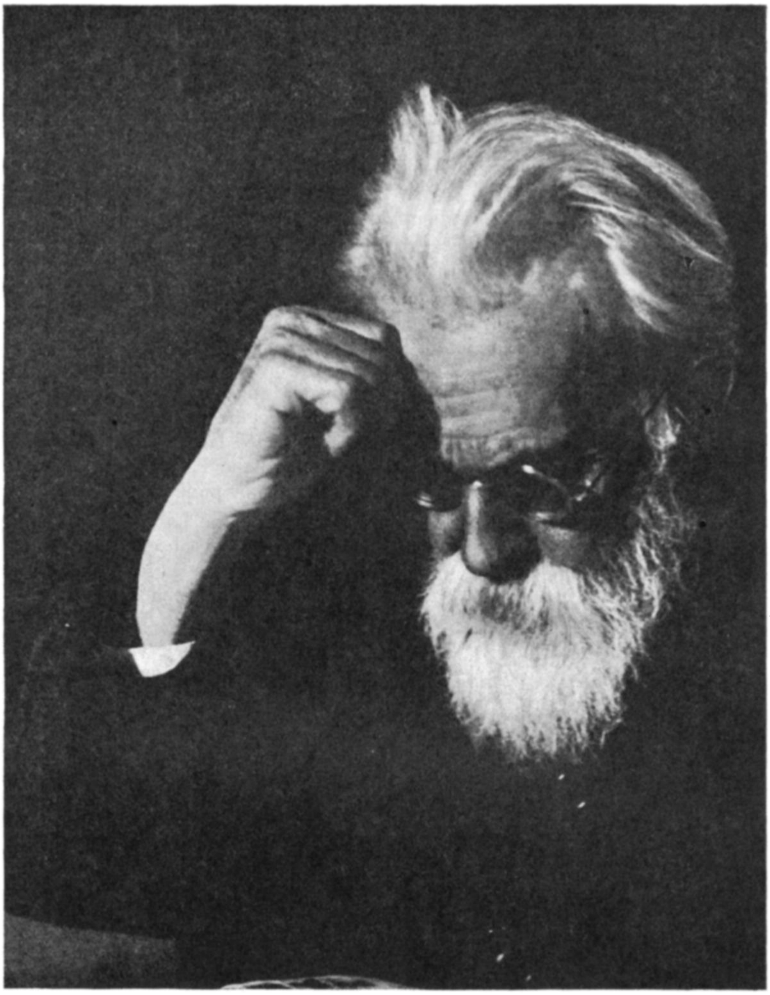

Я смотрю вперед очень оптимистично. Думаю, что мы переживаем не только исторический перелом, но и планетный. Мы живем при переходе в ноосферу.

Сердечный привет. В.Вернадский

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THE BIOSPHERE AND THE NOÖSPHERE

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The following article is composed of an introductory abstract of a paper completed in 1938, and recently published in translation in the Transactions of the Connecticut Academy of Sciences (vol. 35, pp. 483–517), under the editorship of Professor G. E. Hutchinson, and a new essay, written in 1943 and translated from the Russian manuscript by Dr. George Vernadsky of Yale University. The two contributions together present the general intellectual outlook of one of the most remarkable scientific leaders of the present century.

The translation of the quotation under the frontispiece (from a letter to Professor A. Petrunkevitch) is as follows: I look forward with great optimism. I think that we undergo not only an historical, but a planetary change as well. We live in a transition to the noösphere. Cordial greetings, W. Vernadsky.

The table, reproduced in abstract below, that forms the main feature of the earlier paper, calls attention to many properties of living bodies that appear so elementary that they are in danger of neglect. It is an instructive experience to go through the table applying the criteria to the crystallizable viruses, the nature of which was not apparent when the earlier paper was written.—*Editor.*

THE BIOSPHERE

LIVING matter is the totality of all organisms present on the earth at any one time. It is usually such a totality that is important, though in dealing with the effect of man on the processes of this planet, a single individual may be of importance. The living matter of the earth may be regarded as the sum of the average living matter of all the taxonomically recognizable groups. Each of these groups is said to consist of *homogeneous* living matter.

Living matter exists only in the *biosphere* [1]. This includes the whole atmospheric troposphere, the oceans, and a thin layer in the continental regions, extending down three kilometers or more. Man tends to increase the size of the biosphere.

The biosphere is distinguished as the domain of life, but also, and more fundamentally, as the region where changes due to incoming radiation can occur.

Within the biosphere, matter is markedly heterogenous and may be distinguished as inert matter or living matter. The inert matter greatly predominates in mass or volume. There is a continual migration of

† *The sad news of Academician Vernadsky's death on January 6, 1945 has reached us in going to press—Editor.*

atoms from the inert matter to living matter and back again. All the objects of study in the biosphere are to be regarded as the *natural bodies* of the biosphere. They may be of varying complexity, inert, living, or bio-inert as in the case of soil or lake water. The study of all phenomena has a unity, leading to the production of a body of systematized knowledge, the *corpus scientiarum,* which tends to grow like a snowball; this *corpus* includes all systematized knowledge, and is contrasted to the results of philosophy, religion, and art where truth may be revealed intuitively; the systematized history of these activities belongs to the corpus.

Two concepts have been inadequately stressed in the past: (a) Pasteur was correct in regarding the preponderance of optically active compounds as the most characteristic general property of living matter and its products; this idea is of immense importance; (b) the functions of living organisms in the energetics of the biosphere have been seriously neglected. Biogeochemical energy may be expressed in the velocity with which the biosphere could be colonized by a given species. For certain bacteria, the limiting velocity of extension of a dividing chain of cells tending to embrace the whole circumference of the earth would tend to approach the velocity of sound.

Bearing in mind these introductory principles, the difference between living matter and inert matter of the biosphere is expressed in a table, here given in condensed form. The differences in this table are not merely differences with regard to energetics and chemical properties. They also involve a fundamental difference in the spacio-temporal manifestations of living and inert matter. It is suggested that the geometry appropriate to the bodies of living organisms may be different from that appropriate to inert bodies

I

A. Living natural bodies exist only in the biosphere and only as discrete bodies. They have never been observed to arise except from other living bodies. Their entry into the biosphere from cosmic space is hypothetical and has never been proved.

B. *Discrete inert forms are concentrated in the biosphere but are also found much deeper in the earth's crust. They are created in the biosphere, but also enter it from below in volcanic phenomena, and from cosmic space as meteorites and dust.*

II

A. Living natural bodies, in their cellular morphology, protoplasmic nature and reproductive capacity have a unity, which must be connected with their genetic connection with each other in the course of geological time.

B. *Inert natural bodies are extremely diverse and have no common structural or genetic connections.*

III

A. Chemical differences between right and left enantiomorphs characterize the state of physical space occupied by living organisms. Either left or right enantiomorphs predominate.

B. *The left and right enantiomorphs of the same chemical compounds have the same chemical properties in inert bodies. The numbers of dextral and sinistral crystals formed in an inert medium are the same.*

IV

A. New living natural bodies are born only from pre-existing ones. From time to time new generations arise differing from the preceding ones. The rise of the central nervous system has increased the geological rôle of living matter, notably since the end of the Pliocene.

B. *New inert bodies are created in the biosphere irrespective of the natural bodies that previously existed. In general the same kind of natural bodies are formed by inert processes, as were formed two billion years ago. New kinds of inert bodies appear only under the influence of living matter, notably man.*

V

A. There are no liquid or gaseous living bodies, though liquids and gases are present in the mesomorphous or solid living bodies. Spontaneous, largely self-regulated movement is characteristic of living bodies. This may be passive as in reproduction, but the effect of reproduction is for the biosphere to be colonized, by a process comparable to the expansion of a gas.

B. *Liquid and gaseous inert bodies take the form of the receptacles in which they are contained. Solid or mesomorphous inert bodies in general show no motion peculiar to the body as a whole.*

VI

A. There is a continual stream of atoms passing to and from living organisms from and into the biosphere. Within the organisms a vast and changing number of molecules are produced by processes not otherwise known in the biosphere.

B. *Inert natural bodies change only from outside causes, with the exception of radioactive materials.*

VII

A. The number of living natural bodies is quantitatively related to the size of the biosphere.

B. *The number of inert natural bodies is defined by the general properties of matter and energy, and is independent of the size of the planet.*

VIII

A. The mass of living matter has remained fairly constant, being determined by radiant solar energy and the biogeochemical energy of colonization, but apparently the mass increases towards a limit, and the process is not yet complete.

B. *The area of manifestation of inert natural bodies in the biosphere is limited by the size of the latter and increases only as the biosphere is expanded by the motion of living matter.*

IX

A. The minimum size of a living natural body is determined by respiration, and is of the order of 10^{-6} cms. The maximum size has never exceeded $n \cdot 10^4$. The range, 10^{10}, is not great.

B. *The minimum size of an inert natural body in the biosphere is determined by the degree of dispersion of matter and energy, i.e., the size of the ultimate particles of physics. The maximum size is determined by the size of the biosphere. The range is* 10^{40} *or more.*

X

A. The chemical composition of living bodies is a function of their own properties.

B. *The chemical composition of inert bodies is a function of the properties of the medium in which they are formed.*

XI

A. The number of kinds of chemical compounds in living bodies is connected with the kinds of individual organisms and probably reaches many millions.

B. *The number of different kinds of chemical compounds in inert bodies is limited to a few thousands.*

XII

A. The processes in living matter tend to increase the free energy of the biosphere.

B. *All inert processes, save radio-active disintegration, decrease the free energy of the biosphere.*

XIII

A. Living natural bodies are always mesomorphous, and except in latent conditions H and O as water predominate, with an extremely complicated mixture of other compounds. The chemical composition of any one kind of living matter, though not exhibiting stoichiometric relationships, is definitely determined and more constant than the isomorphous mixtures constituting natural minerals.

B. *The chemical composition of inert natural bodies may correspond to nearly pure chemical compounds with precise stoichiometric relations between the elements. In minerals solid solutions predominate.*

XIV

A. Isotopic ratios may be markedly changed by the processes in living matter.

B. *The isotopic ratios do not change markedly in the inert natural bodies of the biosphere, though outside the biosphere, deep in the crust, such changes may occur.*

XV

A. The vast majority of living natural bodies change their forms in the process of evolution. The rates at which these changes occur are, however, widely divergent.

B. *The majority of the inert bodies of the biosphere are stable, and so lack variety.*

XVI

A. The processes of living natural bodies are not reversible in time.

B. *All physiochemical processes in inert natural bodies are reversible in time.*

In everyday life one used to speak of man as an individual, living and moving freely about our planet, freely building up his history. Until recently the historians and the students of the humanities, and to a certain extent even the biologists, consciously failed to reckon with the natural laws of the biosphere, the only terrestrial envelope where life can exist. Basically man cannot be separated from it; it is only now that this indissolubility begins to appear clearly and in precise terms before us. He is geologically connected with its material and energetic structure. Actually no living organism exists on earth in a state of freedom [2]. All organisms are connected indissolubly and uninterruptedly, first of all through nutrition and respiration, with the circumambient material and energetic medium. Outside it they cannot exist in a natural condition.

In our century the biosphere has acquired an entirely new meaning; it is being revealed as a planetary phenomenon of cosmic character. In biogeochemistry we have to reckon with the fact that living organisms actually exist not on our planet alone, and not in the terrestrial biosphere only. It seems to me that so far this has been established beyond doubt only for all so-called "terrestrial planets," that is, for Venus, the Earth, and Mars [3].

The thought of life as a cosmic phenomenon was alive long ago, as evidenced by the archives of science, including Russian science. At the end of the seventeenth century, the Dutch scientist Christian Huygens (1629–1695) put forward that problem in his last work, "Cosmotheoros," which was published after his death. This book, upon the initiative of Peter the Great, was twice published in Russian in the first quarter of the eighteenth century, under the title, "The Book of Contemplation of the World" [4]. In it Huygens established the scientific generalization that "life is a cosmic phenomenon somehow sharply distinct from inert matter." I have recently called this generalization the "Huygens principle" [5]

Living matter, by weight, constitutes an insignificant part of our planet. Presumably, this is observed in the whole course of geological time; in other words, this relation is *geologically eternal* [6]. Living matter is concentrated in a thin but more or less continuous film on the surface of land in the troposphere, in the forests and fields, and permeates the whole ocean. Its quantity is calculated to be of the order of 0.25 per cent of the weight of the biosphere. On land it descends under the surface in non-continuous accumulations, probably down to an average depth of less than 3 kilometers.

THE NOÖSPHERE [7]

We are approaching the climax in the Second World War. In Europe war was resumed in 1939 after an intermission of twenty-one years; it has lasted five years in Western Europe, and is in its third year in our parts, in Eastern Europe. As for the Far East, the war was resumed there much earlier, in 1931, and is already in its twelfth year. A war of such power, duration and strength is a phenomenon unparalleled in the history of mankind and of the biosphere at large. Moreover, it was preceded by the First World War which, although of lesser power, has a causal connection with the present war.

In our country that First World War resulted in a new, historically unprecedented, form of statehood, not only in the realm of economics, but likewise in that of the aspirations of nationalities. From the point of view of the naturalist (and, I think, likewise from that of the historian) an historical phenomenon of such power may and should be examined as a part of a single great terrestrial *geological* process, and not merely as a *historical* process.

In my own scientific work the First World War was reflected in a most decisive way. It radically changed my *geological conception of the world*. It is in the atmosphere of that war that I have approached a conception of nature, at that time forgotten and thus new for myself and for others, a geochemical and biogeochemical conception embracing both inert and living nature from the same point of view [8]. I spent the years of the First World War in my uninterrupted scientific creative work, which I have so far continued steadily in the same direction.

Twenty-eight years ago, in 1915, a "Commission for the Study of the Productive Forces" of our country, the so-called KEPS, was formed at the Academy of Sciences. That commission, of which I was elected president, played a noticeable role in the critical period of the First World War. Entirely unexpectedly, in the midst of the war, it became clear to the Academy of Sciences that in Tsarist Russia there were no precise data concerning the now so-called strategic raw materials, and we had to collect and digest dispersed data rapidly to make up for the lacunae in our knowledge [9]. Unfortunately by the time of the beginning of the Second World War, only the most bureaucratic part of that commission, the so-called Council of the Productive Forces, was preserved, and it became necessary to restore its other parts in a hurry.

By approaching the study of geological phenomena from a geochemical and biogeochemical point of view, we may comprehend the whole of the circumambient nature in the same atomic aspect. Unconsciously such an approach coincides for me with what characterizes the science of the twentieth century and distinguishes it from that of past centuries. *The twentieth century is the century of scientific atomism.*

At that time, in 1917–1918, I happened to be, entirely by chance, in the Ukraine [10], and was unable to return to Petrograd until 1921. During all those years, wherever I resided, my thoughts were directed toward the geochemical and biogeochemical manifestations in the circumambient nature, the biosphere. While observing them, I simultaneously directed both my reading and my reflection toward this subject in an intensive and systematic way. I expounded the conclusions arrived at gradually, as they were formed, through lectures and reports delivered in whatever city I happened to stay, in Ialta, Poltava, Kiev, Simferopol, Novorossiisk, Rostov, and so on. Besides, in almost every city I stayed, I used to read everything available in regard to the problem in its broadest sense. I left aside as much as I could all philosophical aspirations and tried to rest only on firmly established scientific and empiric facts and generalizations, occasionally allowing myself to resort to working scientific hypotheses. Instead of the concept of "life," I introduced that of "living matter," which now seems to be firmly established in science. "Living matter" is the totality of living organisms. It is but a scientific empirical generalization of empirically indisputable facts known to all, observable easily and with precision. The concept of "life" always steps outside the boundaries of the concept of "living matter"; it enters the realm of philosophy, folklore, religion, and the arts. All that is left outside the notion of "living matter."

In the course of geological time living matter morphologically changes according to the laws of nature. The history of living matter expresses itself as a slow modification of the forms of living organisms which genetically are uninterruptedly connected among themselves from generation to generation. This idea had been rising in scientific research through the ages, until, in 1859, it received a solid foundation in the great achievements of Charles Darwin (1809–1882) and Wallace (1822–1913). It was cast in the doctrine of the evolution of species of plants and animals, including man. The evolutionary process is a characteristic only of living matter. There are no manifestations of it in the inert matter of our planet. In the cryptozoic era the same minerals and rocks were being formed which are being formed now [11]. The only exceptions are the bio-inert natural bodies connected in one way or another with living matter [12].

The change in the morphological structure of living matter observed in the process of evolution unavoidably leads to a change in its chemical composition [13].

While the quantity of living matter is negligible in relation to the inert and bio-inert mass of the biosphere, the biogenic rocks constitute a large part of its mass, and go far beyond the boundaries of the biosphere. Subject to the phenomena of metamorphism, they are converted, losing all traces of life, into the granitic envelope, and are no longer part of the biosphere. The granitic envelop of the earth is the area of former biospheres [14]. In Lamarck's book, "Hydrogéologie" (1802), containing many remarkable ideas, living matter, as I understand it, was revealed as the creator of the main rocks of our planet. Lamarck never accepted Lavoisier's (1743–1794) discovery. But that other great chemist, J. B. Dumas (1800–1884), Lamarck's younger contemporary, who did accept Lavoisier's discovery, and who intensively studied the chemistry of living matter, likewise adhered for a long time to the notion of the quantitative importance of living matter in the structure of the rocks of the biosphere.

The younger contemporaries of Darwin, J. D. Dana (1813–1895) and J. Le Conte (1823–1901), both great American geologists (and Dana a mineralogist and biologist as well) expounded, even prior to 1859, the empirical generalization that *the evolution of living matter is proceeding in a definite direction.* This phenomenon was called by Dana "cephalization," and by Le Conte the "psychozoic era." Dana, like Darwin, adopted this idea at the time of his journey around the world, which he started in 1838, two years after Darwin's return to London, and which lasted until 1842 [15].

Empiric notions of a definite direction of the evolutionary process, without, however, any attempt theoretically to ground them, go deeper into the eighteenth century. Buffon (1707–1788) spoke of the "realm of man," because of the geological importance of man. The idea of evolution was alien to him. It was likewise alien to Agassiz (1807–1873), who introduced the idea of the glacial period into science. Agassiz lived in a period of an impetuous blossoming of geology. He admitted that geologically the realm of man had come, but, because of his theological tenets, opposed the theory of evolution. Le Conte points out that Dana, formerly having a point of view close to that of Agassiz, in the last years of his life accepted the idea of evolution in its then usual Darwinian interpretation [16]. The difference between Le Conte's "psychozoic era" and Dana's "cephalization" thus disappeared. It is to be regretted that, especially in our country, this important empirical generalization still remains outside the horizon of our biologists.

The soundness of Dana's principle, which happens to be outside the horizon of our palaeontologists, may easily be verified by anyone willing to do so on the basis of any modern treatise on palaeontology. The principle not only embraces the whole animal kingdom, but likewise reveals itself clearly in individual types of animals. Dana pointed out that in the course of geological time, at least two billion years and probably much more, there occurs an irregular process of growth and perfection of the central nervous system, beginning with the crustacea (whose study Dana used to establish his principle), the molluscs (cephalopoda), and ending with man. It is this phenomenon that he called cephalization. The brain, which has once achieved a certain level in the process of evolution, is not subject to retrogression, but only can progress further.

Proceeding from the notion of the geological rôle of man, the geologist A. P. Pavlov (1854–1929) in the last years of his life used to speak of the *anthropogenic era* in which we now live. While he did not take into the account the possibility of the destruction of spiritual and material values we now witness in the barbaric invasion of the Germans and their allies, slightly more than ten years after his death, he rightly emphasized that man, under our very eyes, is becoming a mighty and ever-growing geological force. This geological force was formed quite imperceptibly over a long period of time. A change in man's position on our planet (his material position first of all) coincided with it. In the twentieth century, man, for the first time in the history of the earth, knew and embraced the whole biosphere, completed the geographic map of the planet Earth, and colonized its whole surface. *Mankind became a single totality in the life of the earth.* There is no spot on earth where man can not live if he so desires. Our people's sojourn on the floating ice of the North Pole in 1937–1938 has proved this clearly. At the same time, owing to the migthy techniques and successes of scientific thought, radio and television, man is able to speak instantly to anyone he wishes at any point on our planet. Transportation by air has reached a speed of several hundred kilometers per hour, and has not reached its maximum. All this is the result of "cephalization," the growth of man's brain and the work directed by his brain.

The economist, L. Brentano, illuminated the planetary significance of this phenomenon with the following striking computation: if a square meter was assigned to each man, and if all men were put close to one another, they would not occupy the area of even the small Lake of Constance between the borders of Bavaria and Switzerland. The remainder of the earth's surface would remain empty of man. Thus the whole of mankind put together represents an insignificant mass of the planet's matter. Its strength is derived not from its matter, but from its brain. If man understands this, and does not use his brain and his work for self-destruction, an immense future is open before him in the geological history of the biosphere.

The geological evolutionary process shows the biological unity and equality of all men, *Homo sapiens* and his ancestors, *Sinanthropus* and others; their progeny in the mixed white, red, yellow, and black races evolves ceaselessly in innumerable generations [17]. This is a *law of nature*. In a historical contest, as for instance in a war of such magnitude as the present one, he finally wins who follows that law. One cannot oppose with impunity the principle of the unity of all men as a law of nature. I use here the phrase "law of nature" as this term is used more and more in the physical and chemical sciences, in the sense of an empirical generalization established with precision.

The historical process is being radically changed under our very eyes. For the first time in the history of mankind the interests of the masses on the one hand, and the free thought of individuals on the other, determine the course of life of mankind and provide standards for men's ideas of justice. Mankind taken as a whole is becoming a mighty geological force. There arises the problem of the *reconstruction of the biosphere in the interests of freely thinking humanity as a single totality.* This new state of the biosphere, which we approach without our noticing it, is the *noösphere.*

In my lecture at the Sorbonne in Paris in 1922–23, I accepted *biogeochemical phenomena* as the basis of the biosphere. The contents of part of these lectures were published in my book, "Studies in Geochemistry," which appeared first in French, in 1924, and then in a Russian translation, in 1927 [18]. The French mathematician Le Roy, a Bergsonian philosopher, accepted the biogeochemical foundation of the biosphere as a starting point, and in his lectures at the Collège de France in Paris, introduced in 1927 the concept of the noösphere as the stage through which the biosphere is now passing geologically [19]. He emphasized that he arrived at such a notion in collaboration with his friend Teilhard de Chardin, a great geologist and palaeontologist, now working in China.

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 before him. It may be that the generation of our grandchildren will approach their blossoming.

Here a new riddle has arisen before us. *Thought is not a form of energy.* How then can it change material processes? That question has not as yet been solved. As far as I know, it was first posed by an American scientist born in Lvov, the mathematician and biophysicist Alfred Lotka [20]. But he was unable to solve it. As Goethe (1740–1832), not only a great poet but a great scientist as well, once rightly remarked, in science we only can know *how* something occurred, but we cannot know *why* it occurred.

As for the coming of the noösphere, we see around us at every step the empirical results of that "incomprehensible" process. That mineralogical rarity, native iron, is now being produced by the billions of tons. Native aluminum, which never before existed on our planet, is now produced in any quantity. The same is true with regard to the countless number of artificial chemical combinations (biogenic "cultural" minerals) newly created on our planet. The number of such artificial minerals is constantly increasing. All of the *strategic raw materials* belong here. Chemically, the face of our planet, the biosphere, is being sharply changed by man, consciously, and even more so, unconsciously. The aerial envelope of the land as well as all its natural waters are changed both physically and chemically by man. In the twentieth century, as a result of the growth of human civilization, the seas and the parts of the oceans closest to shore become changed more and more markedly. Man now must take more and more measures to preserve for future generations the wealth of the seas which so far have belonged to nobody. Besides this, new species and races of animals and plants are being created by man. Fairy tale dreams appear possible in the future: man is striving to emerge beyond the boundaries of his planet into cosmic space. And he probably will do so.

At present we cannot afford not to realize that, in the great historical tragedy through which we live, we have elementally chosen the right path leading into the noösphere. I say elementally, as the whole history of mankind is proceeding in this direction. The historians and political leaders only begin to approach a comprehension of the phenomena of nature from this point of view. The approach of Winston Churchill (1932) to the problem, from the angle of a historian and political leader, is very interesting [21].

The noösphere is the last of many stages in the evolution of the biosphere in geological history. The course of this evolution only begins to become clear to us through a study of some of the aspects of the biosphere's geological past. Let me cite a few examples. Five hundred million years ago, in the Cambrian geological era, skeletal formations of animals, rich in calcium, appeared for the first time in the biosphere; those of plants appeared over two billion years ago. That calcium function of living matter, now powerfully developed, was one of the most important evolutionary factors in the geological change of the biosphere [22]. A no less important change in the biosphere occurred from seventy to one hundred and ten million years ago, at the time of the Cretaceous system, and especially during the Tertiary. It was in this epoch that our green forests, which we cherish so much, were formed for the first time. This is another great evolutionary stadium, analogous to the noösphere. It was probably in these forests that man appeared, around fifteen or twenty million years ago.

Now we live in the period of a new geological evolutionary change in the biosphere. We are entering the noösphere. This new elemental geological process is taking place at a stormy time, in the epoch of a destructive world war. But the important fact is that our democratic ideals are in tune with the elemental geological processes, with the laws of nature, and with the noösphere. Therefore we may face the future with confidence. It is in our hands. We will not let it go.

Borovoe, July 22/Moscow, December 15, 1943.

NOTES AND REFERENCES

1. The concept of "biosphere," that is, of the "area of life," was introduced into biology by Lamarck (1744–1829) in Paris in the early nineteenth century, and into geology by Suess (1831–1914) in Vienna at the close of the same century. On the biosphere, see W. Vernadsky, *Ocherki geokhimii,* 4th edition, Moscow-Leningrad. Index; *Biosfera* (The Biosphere) Leningrad, 1926; French edition, Paris, 1929.
2. That remarkable scientist, Caspar Wolf (1733–1794), a member of the St. Petersburg Academy of Sciences, who though not a Russian by birth, dedicated his whole life to Russia, clearly expressed the connection between organisms and their medium in a book published in German in St. Petersburg in 1789, the year of the great French Revolution, under the title, *Von d. eigenthüml. Kraft d. Vegetabl. sowohl auch d. animal. Substanz als Erläuterung zu zwei Preisschriften über d. Nutritions-kraft* (On the Specific and Active Force Proper to the Vegetal and Animal Substance).

Unlike the great majority of the biologists in his time, he tended toward the ideas of Newton rather than those of Descartes.

It it to be regretted that the manuscripts left after Wolf's death have been, as yet, neither studied nor published. In 1927 the Commission on the History of Knowledge at the Academy of Sciences decided to do this work, but it could not be accomplished because of the constant changes in the Academy's approach toward the study of the history of science. Now that work at the Academy has been reduced to a minimum, which is harmful to the cause.

3. See my article on *The Geological Envelopes of the Earth as a Planet,* Izvestiia of the Academy of Sciences, Geographical and Geophysical Series, 1942, p. 251. Cf. H. Spenser Jones, *Life on Other Worlds,* New York, 1940; R. Wildt in Proc. Amer. Philos. Soc. 81 (1939), p. 135. A Russian translation of Wildt's study, regrettably not in full (which is not indicated in the paper) appeared in the Astronomicheskii Zhurnal, vol. XVII (1940), no. 5, p. 81ff. By now, a new study by Wildt has appeared, *Geochemistry and the Atmosphere of Planets* (1941), but, to our regret, no copy of it has so far reached us.

   The Biogeochemical Laboratory of the Academy of Sciences in Moscow, now renamed the Laboratory of Geochemical Problems, in cooperation with the Institute of Microbiology of the same Academy (corresponding member, B. L. Isachenko) set the problem of cosmic life as a current scientific problem as early as 1940. This work was stopped by the war, but will be resumed at the first opportunity.
4. It would deserve a new edition in modern Russian, with commentaries.
5. See *Ocherki geokhimii,* pp. 9, 288, and my book *Problemy biogeokhimii* (The Problems of Biogeochemistry) III (in press).
6. *Problemy biogeokhimii,* III.
7. The word "noösphere" is composed from the Greek terms *noos,* mind, and *sphere,* the last used in the sense of an envelope of the earth. I treat the problem of the noösphere in more detail in the third part of my book, now being prepared for publication, on *The Chemical Structure of the Biosphere of the Earth as a Planet, and its Surroundings.*
8. It should be noted that in this connection I came upon the forgotten thoughts of that original Bavarian chemist, C. Schoenbein (1799–1868) and of his friend, the English physicist of genius, M. Faraday (1791–1867). As early as the beginning of the eighteen-forties, Schoenbein attempted to prove that a new division should be created in geology—geochemistry, as he called it. See W. Vernadsky, *Ocherki geokhimii* (Studies in Geochemistry), 4th edition, Moscow-Leningrad, 1934, pp. 14, 290.
9. On the significance of KEPS see A. E. Fersman. *Voina i strategicheskoe syrie* (The War and Strategic Raw Materials). Krasnoufimsk, 1941, p. 48.
10. See my article, *Out of my Recollections: The First Year of the Ukrainian Academy of Sciences,* to appear in the Jubilee volume of the Ukrainian Academy of Sciences, in commemoration of its twenty-fifth anniversary.
11. In accordance with modern American geologists as, for example, Charles Schuchert (Schuchert and Dunbar, *A Textbook of Geology,* II, New York, 1941, p. 88ff.), I call the Cryptozoic era that period which formerly had been called the Azoic, or the Archaeozoic, era. In the Cryptozoic era the morphological preservation of the remnants of organisms dwindles almost to nothing, but the existence of life is revealed in the organogenic rocks, the origins of which arouse no doubts.
12. On the bio-inert bodies see W. I. Vernadsky, *Problems of Biogeochemistry, II.* Trans. Conn. Acad. Arts Sci., vol. 35 (1944), pp. 493–494. Such are, for example, the soil, the ocean, the overwhelming majority of terrestrial waters, the troposphere, and so on.
13. This problem urgently needs experimental verification. It has been set forth by the Laboratory of Geochemical Problems in collaboration with the Palaeontological Institute of the Academy of Sciences, in the plan of our work for 1944.
14. See my basic work referred to in Note 7.
15. One should not fail to note here that the expedition during which Dana came to his conclusions concerning cephalization, the coral islands, and so on, actually and historically was closely connected with the exploration of the Pacific by Russian navigators, especially Krusenstern (1770–1846). See D. Gilman, *The Life of J. D. Dana,* New York, 1899. The chapter on the oceanic expedition in this book was written by Le Conte. Le Conte's book, *Evolution* (1888), has not been accessible to me. His autobiography was published in 1903: W. Armes, Editor, *The Autobi-*

ography of Joseph Le Conte. For his biography and bibliography see H. Fairchild in Bull. Geol. Soc. Amer. 26 (1915), p. 53. It was the report on the Russian travels, published in German in 1827, which spurred the American lawyer, John Reynolds, to insist on the organization of a similar American scientific oceanic expedition. Owing to Reynolds' persistence, the expedition eventually materialized, but not until eleven years afterwards, in 1838. This was the Wilkes expedition, which finally proved the existence of the Antarctic.

On Reynolds see the Index in *Centenary Celebration: Wilkes Exploring Expedition of the U. S. Navy, 1838–1842*, Proc. Amer. Philos. Soc., 82, No. 5 (1940). It is to be regretted that our expeditions in the Pacific, so active in the first half of the nineteenth century, were later discontinued for a long time (almost until the Revolution), following the death of both Emperor Alexander I (1777–1825) and Count N. P. Rumiantsov (1754–1826)—that remarkable leader of Russian culture who equipped the "Riurik" expedition (1815–1818) out of his private funds.

In the Soviet period K. M. Deriugin's (1878–1936) expedition should be mentioned; its precious and scientifically important materials have been so far only partly studied and remain unpublished. Such an attitude toward scentific work is inadmissible. The Zoological Museum of the Academy of Sciences must fulfill this scientific and civic duty.

16. D. Gilman, *o.c.*, p. 255.
17. I and my contemporaries have imperceptibly lived through a drastic change in the comprehension of the circumambient world. In the time of my youth it seemed both to me and to others that man had lived through a historical time only, within the span of a few thousand years, at best a few tens of thousand of years. Now we know that man has been consciously living through tens of millions of years. He consciously lived through the glacial period in both Eurasia and North America, through the formation of Eastern Himalaya, and so on. The division of historical and geological time is leveled out for us.
18. The last revised edition of my *Ocherki Geokhimii* (Problems of Geochemistry) appeared in 1934. In 1926 the Russian edition of *Biosfera* (The Biosphere) came out, and in 1929 its French edition. My *Biogeokhimicheskie Ocherki* (Biogeochemical Studies) was published in 1940. The publication of *Problemy biogeokhimii* (Problems of Biogeochemistry) was begun in 1940. (A condensed English translation of Part II appeared, under the editorship of G. E. Hutchinson, in Trans. Conn. Acad. Arts Sci., vol. 35, in 1944.) Part III is in press. *Ocherki geokhimii* was translated into German and Japanese.
19. Le Roy's lectures were at once published in French: *L'exigence idéaliste et le fait d'évolution,* Paris, 1927, p. 196.
20. A. Lotka, *Elements of Physical Biology,* Baltimore, 1925, p. 405 f.
21. W. S. Churchill, *Amid These Storms: Thoughts and Adventures,* New York, 1932, p. 274 f. I plan to return to this problem elsewhere.
22. I deal with the problem of the biogeochemical functions of organisms in the second part of my book, *The Chemical Structure of the Biosphere* (see Note 7).