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The British Journal for the History of Science / Volume 46 / Issue 02 / June 2013, pp 287 - 310
DOI: 10.1017/S0007087412000015, Published online: 15 March 2012

BJHS **46**(2): 287–310, June 2013.
doi:10.1017/S0007087412000015 First published online 15 March 2012

V.I. Vernadskii and the development of biogeochemical understandings of the biosphere, *c.*1880s–1968

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Abstract. General notions of the biosphere are widely recognized and form important elements of contemporary debate concerning global environmental change, helping to focus attention on the complex interactions that characterize the Earth's natural systems. At the same time, there is continued uncertainty over the precise definition of the concept allied to a relatively limited critique of its early development, which was linked closely to advances in the natural sciences during the late nineteenth century and particularly, it is argued here, to the emergence of biogeochemistry. In the light of this, the principal aim of the paper is to explore the development and subsequent dissemination of biogeochemical renderings of the biosphere concept, focusing primarily on the work of the Russian biogeochemist Vladimir Ivanovich Vernadskii (1863–1945). The paper identifies four key moments which, it is argued, help to explain the development and subsequent dissemination of a biogeochemical understanding of the biosphere. First, we draw attention to the particularities of St Petersburg's natural-science community during the late nineteenth century, arguing that this was instrumental in providing the basis for Vernadskii's future work related to the biosphere. Second, we consider the ways in which Vernadskii's ideas concerning the biosphere were able to move to the West during the first half of the twentieth century with specific reference to his links with the French scientists Pierre Teilhard de Chardin and Edouard Le Roy, and the US-based ecologist George Evelyn Hutchinson. Third, we reflect more purposefully on matters of reception and, in particular, the emergence of a set of circumstances within Western ecological science after 1945, which encouraged a positive engagement with biogeochemical understandings of the biosphere. Finally, we examine the 1968 UNESCO-sponsored Biosphere Conference, which represented

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Research for this paper has been funded primarily by an ESRC Large Research Grant: RES-062-23-1734 (The USSR and its contribution to global environmental scientific understanding and policy prescription, 1945–1991). Additional archival and library work in London and Paris during 2007–2008 was supported by the Department of Central and East European Studies, University of Glasgow. Earlier versions of this paper have been given at the Fourth European Society for Environmental History Conference (Amsterdam, April 2007); the annual conference of the British Association of Slavonic and East European Studies (Cambridge, March 2008); the European University at St Petersburg (February 2008); and the Department of Geographical and Earth Sciences, University of Glasgow (May 2008). The authors would like to thank participants at these events for useful comments and associated discussion. Further thanks are due to Jens Boel and Mahmoud Ghander for their considerable help in facilitating access to the necessary UNESCO archival materials; William Clark and Nancy Dickson for facilitating a visit to the Center for International Development, Harvard University; Malcolm Hadley for helpful advice during the early stages of the paper; and Irina Vibe for facilitating work in St Petersburg during October 2010. The constructive comments of the anonymous referees are also gratefully acknowledged.

the first time the biosphere concept was employed at the international level. Furthermore, this event was in many ways a high point for a specifically biogeochemical approach, with the subsequent popularization of the biosphere concept during the course of the 1970s helping to broaden the discourse markedly.

Biogeochemical conceptualizations of the biosphere emerged strongly during the course of the twentieth century, grounded on deepening understandings of the Earth's natural and physical systems and encouraged by growing concerns over the human impact on such systems.[1] Related insight was particularly useful in opening up the complex relationships that exist between living and non-living matter. More specifically, the developing understanding of such interactions provided, amongst other things, the basis for work concerning the management and rational use of natural resources which emerged as a key focal point of international scientific activity from the 1960s onwards. The search for a comprehensive approach towards the management of global physical and ecological systems remains a key feature of contemporary scientific and policy agendas in the guise of climate-change science, sustainable development, earth system analysis and related initiatives.[2] While general notions of the biosphere are widely recognized and form important elements of contemporary debates concerning global environmental change, there is continuing uncertainty over the precise definition of the concept.[3] Furthermore, the origins of biogeochemical understandings of the biosphere are typically obscured. In recognition of such definitional uncertainty and in the light of the formative relevance of specifically biogeochemical approaches to the biosphere idea for the shape of environmental management initiatives during the twentieth century, this paper aims to explore the emergence, development and subsequent dissemination of biogeochemical renderings of the biosphere concept.

In order to develop the main focus of the paper and track the emergence and subsequent movement of biogeochemical understandings of the biosphere, we draw from long-standing and ongoing debates within the sociology and geography-of-science literatures, which encourage, amongst other things, a critical examination of the sociocultural underpinnings of scientific endeavour.[4] This collection of literatures covers

1 Biogeochemistry is concerned broadly with understanding the complex interactions that take place between living and non-living matter within and between the Earth's lithosphere, hydrosphere, atmosphere and biosphere. The Russian academic Vladimir Ivanovich Vernadskii is generally acknowledged as the first person to utilize this term as part of his work concerning the biosphere. However, the term has a long intellectual heritage, with key conceptual insights traceable to at least the seventeenth century. See Eville Gorham, 'Biogeochemistry: its origins and development', *Biogeochemistry* (1991) 13, pp. 199–239, 224–225. For contemporary developments in this field see William H. Schlesinger (ed.), *Treatise on Geochemistry*, vol. 8: *Biogeochemistry*, Amsterdam: Elsevier Pergamon, 2004.

2 See Frank Biermann, Michele M. Betsill, Susana Camargo Vieira, Joyeeta Gupta *et al*., 'Navigating the anthropocene: the Earth System Governance Project strategy paper', *Current Opinion in Environmental Sustainability* (2010) 2, pp. 202–208; Martina Maria Keitsch, 'Editorial: sustainability and science – challenges for theory and practice', *Sustainable Development* (2010) 18, pp. 241–244.

3 For example, see Richard John Huggett, *Geoecology: An Evolutionary Approach*, London: Routledge, 1995; *idem*, 'Ecosphere, biosphere, or gaia? What to call the global ecosystem', *Global Ecology and Biogeography* (1999) 8, pp. 425–431.

4 For recent reviews see Diarmid A. Finnegan, 'The spatial turn: geographical approaches in the history of science', *Journal of the History of Biology* (2008) 41, pp. 369–388; Jan Golinski, *Making Natural Knowledge:*

significant ground in trying to argue for, as well as explain, the complex and multiple ways in which scientific knowledge and practice are formed, moulded, shaped and disseminated within and between different sociocultural contexts. This paper exemplifies a number of specific strands of this body of work. First, the paper provides an indication of the affective qualities of space and place and, more particularly, the ways in which the specificities of place (variously defined) can play a role in the generation as well as the reception of scientific ideas as they are reworked and validated in the light of prevailing sociocultural frameworks.[5] Second, and reflecting the observations and work of several authors, the paper remains sensitive to the tensions that can exist between the influence of local particularities on knowledge creation and interpretation and a plethora of exogenous influences associated with network creation, alliance building, and the associated flow of tangible and intangible 'things', ranging from books to standardized instrumentation, technologies and 'ways of doing'.[6] Third, such concerns link with closely related meditations on the different ways in which scientific understanding might travel and move through space and time.[7] An interest in the movement of knowledge is for some an important counter to the tendency towards an overreliance on 'thick', localized studies of knowledge creation which can shy away from explaining why and how certain types of knowledge are able to travel significant distances and influence multiple contexts, a point raised influentially towards the end of Ophir and Shapin's 1991 paper entitled 'The place of knowledge'.[8] Livingstone's (2005) reflections on how texts are read in different places and times, with a specific focus on the varying reception of Darwin's theory of evolution, is useful amongst other things in highlighting the 'jagged' way in which knowledge moves between places, with textual reception mediated by a host of contextual sociocultural factors.[9] Shapin opens up a further vista of possibility by drawing attention to the potential importance of less tangible facilitators of knowledge exchange such as trust.[10]

Constructivism and the History of Science, Chicago: The University of Chicago Press, 2005; David N. Livingstone, *Putting Science in Its Place: Geographies of Scientific Knowledge*, Chicago: The University of Chicago Press, 2003; Richard C. Powell, 'Geographies of science: histories, localities, practices, futures', *Progress in Human Geography* (2007) 31, pp. 309–329; James A. Secord, 'Knowledge in transit', *Isis* (2004) 95, pp. 654–672; Charles W.J. Withers, 'Place and the "spatial turn" in geography and in history', *Journal of the History of Ideas* (2009) 70, pp. 637–658, 650–658.

5 Livingstone, op. cit. (4), p. 11; see also Trevor J. Barnes, 'Placing ideas: genius loci, heterotopia and geography's quantitative revolution', *Progress in Human Geography* (2004) 28, pp. 565–595.

6 For example, Finnegan, op. cit. (4), p. 370; Bruno Latour, *Pandora's Hope: Essays on the Reality of Science Studies*, Cambridge, MA: Harvard University Press, 1999; Secord, op. cit. (4), pp. 659–660; Withers, op. cit. (4), p. 654.

7 Steven Shapin, 'Placing the view from nowhere: historical and sociological problems in the location of science', *Transactions of the Institute of British Geographers NS* (1998) 23, pp. 5–12, 6–8; Golinski, op. cit. (4), p. xii; Livingstone, op. cit. (4); Powell, op. cit. (4), pp. 312–313; Secord, op. cit. (4).

8 Adi Ophir and Steven Shapin, 'The place of knowledge: a methodological survey', *Science in Context* (1991) 4, pp. 3–21; also see Powell, op. cit. (4), pp. 312–313; Secord op. cit. (4), p. 660.

9 David N. Livingstone, 'Science, text and space: thoughts on the geography of reading', *Transactions of the Institute of British Geographers NS* (2005) 30, pp. 391–401.

10 Shapin, op. cit. (7), pp. 7–8.

Bearing such complexities in mind, we attempt in this paper to sketch a series of vignettes which are intended to highlight key moments in the development and subsequent dissemination of a biogeochemical understanding of the biosphere. After a brief overview of the origins of the biosphere idea broadly conceived, the first part of the paper is concerned predominantly with the work of the Russian biogeochemist Vladimir Ivanovich Vernadskii. While wary of oversimplification, the early articulation of a specifically biogeochemical understanding of the biosphere can be linked strongly to his endeavours in this area.[11] It is suggested that the specific characteristics of the natural-science community in late tsarist St Petersburg played an influential role in laying the intellectual foundations for Vernadskii's subsequent formulation of the biosphere idea during the early part of the twentieth century, with an emphasis being placed on the existence of complex interconnections between living and non-living elements of nature. The second substantive section of the paper reflects on the way in which Vernadskii's ideas concerning the biosphere and related areas of thought were able to move to the West during the course of the twentieth century, with specific reference to his visit to Paris in the 1920s as well as the particularities of his connection with the US-based ecologist George Evelyn Hutchinson. The third section of the paper moves away from issues concerning the generation and dissemination of scientific knowledge in order to reflect more purposively on matters of reception. In particular, it highlights the emergence of a set of circumstances within the West, and particularly the United States, after 1945, which encouraged a positive engagement with biogeochemical understandings of the biosphere, as advances in ecological science coincided with growing concerns over the links between human activity and the wider environment. The final part of the paper moves the focus yet again in order to examine the 1968 UNESCO-sponsored Biosphere Conference. This conference represented the first time that the biosphere concept was employed at the international level and can be seen as a high point for a specifically biogeochemical approach with the subsequent popularization of the biosphere concept during the course of the 1970s helping to broaden the discourse markedly.[12]

11 Jacques Grinevald, 'Introduction: the invisibility of the Vernadskian revolution', in Vladimir I. Vernadsky, *The Biosphere*, New York: Copernicus, 1998, pp. 20–32; Nicholas Polunin and Jacques Grinevald, 'Vernadsky and biospheral ecology', *Environmental Conservation* (1988) 15, pp. 117–122.

12 Lynton Keith Caldwell, *Between Two Worlds: Science, the Environmental Movement, and Policy Choice*, Cambridge: Cambridge University Press, 1990, pp. 38–61; see also the work of Grinevald, op. cit. (11), p. 21; Polunin and Grinevald, op. cit. (11); Barbara Ward and René Dubos, *Only One Earth: The Care and Maintenance of a Small Planet*, New York: W.W. Norton & Company, 1983; Donald Worster, *Nature's Economy: A History of Ecological Ideas*, 2nd edn, Cambridge: Cambridge University Press, 1994, pp. 358–359. Efforts were made to maintain the emphasis on Vernadskii's intellectual heritage during the 1970s (for example, see G. Evelyn Hutchinson, 'The biosphere', *Scientific American* (1970) 223(3), pp. 45–53), or else at least the essence of his general approach (for example, R.F. Dasmann, *Planet in Peril? Man and the Biosphere Today*, Harmondsworth: Penguin Books–UNESCO, 1972). Furthermore, academic journals such as *Environmental Conservation* (established in 1974) have consistently engaged with the specifics of his legacy (e.g. Viktor A. Kovda, 'Changing trends in the biosphere and in biogeochemical cycles', *Environmental Conservation* (1976) 3, pp. 161–170; *idem*, 'The Earth's living matter: biosphere and soils', *Environmental Conservation* (1993) 20, pp. 199–204).

Origins of the biosphere concept and the work of V.I. Vernadskii

The biosphere concept has a long history but the first use of the term is generally credited to the Swiss geologist Eduard Suess in 1875. Importantly, he employed the term in a rather generalized manner in order to highlight the area of the Earth's surface characterized by life.[13] Following Suess's intervention, references to the biosphere as a sphere of life distinct from the other non-living 'spheres' were not infrequent within the academic literature during the late nineteenth and early twentieth centuries. For example, Sir John Murray, addressing the British Association in 1899 within the context of a lecture on oceanography, noted,

> When we regard our globe with the mind's eye, it appears at the present time to be formed of concentric spheres, very like, and still very unlike, the successive coats on an onion. Within is situated the vast nucleus or *centrosphere*; surrounding this is what may be called the *tektosphere*, a shell of materials in a state bordering on fusion, upon which rests and creeps the *lithosphere*. Then follow *hydrosphere* and *atmosphere*, with the included *biosphere*. To the interaction of these six geospheres, through energy derived from internal and external sources, may be referred all the existing superficial phenomena of the planet.[14]

Efforts to date the first usage of the term 'biosphere' are important and yet draw attention away from the extensive intellectual heritage underpinning the concept. Indeed, a closer examination of the biosphere concept reveals a range of implicit understandings, many of which date back to at least the late eighteenth century.[15] One of the defining characteristics of the concept that emerged strongly during the twentieth century challenged the notion of living matter as a more or less self-contained entity in order to acknowledge the potential for such matter to influence the Earth's physical environment. In fact, purposeful consideration of the intimate processes connecting living and non-living matter is typically traced back to the work of Joseph Priestley, Immanuel Kant, Alexander von Humboldt, Jean Baptiste Lamarck and others during the late eighteenth and early nineteenth centuries,[16] whilst more specific work relating to the interaction between humankind and the natural environment also began to appear during the course of the nineteenth century.[17] The capacity of living matter to engender

13 Vaclav Smil, *The Earth's Biosphere: Evolution, Dynamics, and Change*, Cambridge, MA: The MIT Press, 2002, pp. 1–2.

14 John Murray, 'Oceanography', *Geographical Journal* (1899) 14, pp. 426–441, 435, emphases in original.

15 Jacques Grinevald, 'Sketch for a history of the idea of the biosphere', in Peter Bunyard (ed.), *Gaia in Action: Science of the Living Earth*, Edinburgh: Floris Books, 1996, pp. 34–53.

16 Alexej M. Ghilarov, 'Vernadsky's biosphere concept: an historical perspective', *Quarterly Review of Biology* (1995) 70, pp. 193–203; Gorham, op. cit. (1); Malcolm Nicolson, 'Alexander von Humboldt, Humboldtian science and the origins of the study of vegetation', *History of Science* (1987) 25, pp. 167–194; *idem*, 'Historical introduction', in Alexander von Humboldt, *Personal Narrative of a Journey to the Equinoctial Regions of the New Continent*, London: Penguin, 1995, pp. ix–xxxiv. See also Daniel B. Botkin, *Discordant Harmonies: A New Ecology for the Twenty-First Century*, Oxford: Oxford University Press, 1990, pp. 140–145.

17 For example, George Perkins Marsh, *Man and Nature*, Seattle: University of Washington Press, 2003. See also Peter J. Bowler, *The Earth Encompassed: A History of the Environmental Sciences*, New York: W.W. Norton, 1992, pp. 318–323.

fundamental changes in the geochemical structure of the Earth is most obvious when life is viewed in its entirety and over the course of geological time. For example, the synthetic work of the twentieth-century American natural scientist Preston Cloud drew attention to the significant geochemical impact of life as it evolved over millions of years:[18]

> The appearance of an Archean biosphere [>2.5 billion years ago] initiated a set of interactions among biosphere, atmosphere, hydrosphere, and lithosphere that marked an irreversible change in the surface processes of the planet. Whereas, on the one hand, life on Earth is sustained and molded by its physical environment, the properties of Earth's air, water, and seemingly solid surface are themselves powerfully shaped by interactions with the contemporary biomass – the sum of which, with its environment, we call the biosphere.[19]

Developing this line of thought, Botkin notes a whole range of 'biological perturbations' which have resulted in substantial and irreversible changes to the air and water, as well as to inert matter,[20] over the course of the Earth's history and include events such as the emergence of the process of photosynthesis and aerobic respiration.[21]

V.I. Vernadskii and biogeochemical understandings of the biosphere

While generalized appreciations of the biosphere concept were at least familiar to certain Western (and Russian) scholars concerned with describing and understanding the Earth's physical systems during the early part of the twentieth century, limited effort had been expended in order to develop and sharpen this understanding. This conceptual void was filled to a large extent by the work of the aforementioned Russian biogeochemist, Vladimir Ivanovich Vernadskii.[22] In attempting to understand the reasons behind Vernadskii's particular formulation of the biosphere concept, a focus on his early education and university experience provides some useful insight.

Following an eight-year period living in Kharkov (present-day Ukraine), Vernadskii's family moved back to the city of St Petersburg when Vladimir Ivanovich was thirteen years old (in 1876). With the completion of his secondary education, Vernadskii entered the natural-science department of the physical-mathematics faculty of St Petersburg University in 1881.[23] Vernadskii ranged across several disciplinary fields and spheres of activity during the course of his professional life but developed an early interest in crystallography and mineralogy.[24] Importantly, it was during his university years that

18 For example, see Preston Cloud, *Adventures in Earth History*, San Francisco: W.H. Freeman and Company, 1970; *idem*, *Oasis in Space: Earth History from the Beginning*, New York: W.W. Norton and Company, 1988.

19 Cloud, *Oasis in Space*, op. cit. (18), pp. 165–166.

20 Botkin, op. cit. (16), pp. 147–148.

21 Vernadskii pursued a similar line of thought whilst reflecting on the biosphere's evolution towards the noosphere, of which more below. See W.I. Vernadsky, 'The biosphere and the noösphere', *American Scientist* (1945) 33, pp. 1–12, 10.

22 For example, see Grinevald, op. cit. (11); *idem*, op. cit. (15).

23 Kendall E. Bailes, *Science and Russian Culture in an Age of Revolutions: V.I. Vernadsky and His Scientific School, 1863–1945*, Bloomington: Indiana University Press, 1990, pp. 8–15.

24 Vernadskii's interest in crystallography and mineralogy would broaden over time to incorporate a focus on chemical processes and associated elements (geochemistry) as well as the complex interplay between

Vernadskii was exposed to the interdisciplinary work of the soil scientist Vasilii Vasil'evich Dokuchaev, who was one of several influential professors active in the physical-mathematics faculty at that time. Furthermore, Dokuchaev would play a key role in directing the early research activities of Vernadskii.[25] Dokuchaev spent many years undertaking extensive fieldwork expeditions in parts of European Russia, and particularly the steppe region, in order to assess soil resources.[26] As a result of this activity Dokuchaev developed a sophisticated understanding of soil as an independent natural body, placing considerable emphasis on the interplay between organic and inorganic factors in the genesis of different soil types.[27] His work highlighted the tendency for a natural zonation of soil types to develop as a consequence of the ordered and predictable interaction of soil-forming factors, among which climate played a leading role.[28] His general insights concerning the interaction of living and non-living matter as an integral part of soil formation, as well his work relating to the existence of soil zones, broadening into natural zones in his later writings, proved influential across significant areas of Russian natural science and found clear expression in the work of the forest scientist G.F. Morozov, geobotanist/geographer G.I. Tanfil'ev, geobotanist V.N. Sukachev and many others. Vernadskii formed a strong attachment to Dokuchaev as a student and the two developed a close working relationship up to the death of Dokuchaev in 1903.[29] Vernadskii's later work in the field of biogeochemistry, as well as his ideas concerning the biosphere, reflected Dokuchaev's awareness of the complex and intimate relations between organic and inorganic matter.[30]

Vernadskii's biosphere concept

Vernadskii's interest in mineralogy, allied to a deepening understanding of the complex interplay between living and non-living entities, helped to underpin his pioneering work in the area of biogeochemistry. His associated formulation of the biosphere concept

biological, chemical and geological processes within the natural environment (biogeochemistry). See Alexander Yanshin, 'Introduction', in *Geochemistry and the Biosphere: Essays by Vladimir I. Vernadsky* (ed. Frank B. Salisbury), Santa Fe, NM: Synergetic Press, 2007, xvii–xlii, xx–xxxv.

25 See Bailes, op. cit. (23), pp. 17–21.

26 For example, see Catherine Evtuhov, 'The roots of Dokuchaev's scientific contributions: cadastral soil mapping and agro-environmental issues', in Benno P. Warkentin (ed.), *Footprints in the Soil: People and Ideas in Soil History*, Amsterdam: Elsevier, 2006, pp. 125–148; I. Krupenikov and L. Krupenikov, *Puteshestviya i ekspeditsii V.V. Dokuchaeva*, Moscow: Gosudarstvennoe izdatel'stvo geograficheskoi literatury, 1949; David Moon, 'The environmental history of the Russian steppes: Vasilii Dokuchaev and the harvest failure of 1891', *Transactions of the RHS* (2005) 15, pp. 149–174.

27 K.D. Glinka, *Dokuchaiev's Ideas in the Development of Pedology and Cognate Sciences*, Leningrad: Academy of Sciences of the USSR, 1927.

28 V.V. Dokuchaev, 'Prirodnye pochvennye zony. Sel'skokhozyaistvennye zony. Pochvy Kavkaza', in *V.V. Dokuchaev. Sochineniya VI: Preobrazovanie prirody stepei*, Moscow and Leningrad: Izdatel'stvo Akademii Nauk SSSR, 1951, pp. 460–492.

29 For example, see I.N. Skrynnikova, 'O perepiske V.V. Dokuchaeva i V.I. Vernadskogo', in S.I. Vavilov, Kh.S. Koshtoyants, N.A. Figurovskii *et al.* (eds.), *Nauchnoe nasledstvo, Tom vtoroi*, Moscow: Izdatel'stvo Akademii Nauk SSSR, 1951, pp. 745–760.

30 See also Bailes, op. cit. (23), pp. 19–20.

developed over a long period of time and emerged in its mature form in his 1926 Russian-language book entitled *The Biosphere*.[31] In this work he placed the biosphere within a cosmic framework powered by the Sun and reflected on the ways in which living matter (understood in its entirety) might influence the chemical and geological composition of inert elements in the atmosphere, lithosphere and hydrosphere.[32] The opening section of the book drew attention to the scope of his ideas:

> *The face of the Earth* appears to us as both original and singular in its origin, different and unique from other celestial bodies – standing out from celestial space.
>
> On the face of the Earth is revealed the surface of our planet, its *biosphere*, its external area, delimiting it from cosmic space. The face of the Earth becomes visible owing to the penetration of light radiation from heavenly bodies, mainly the Sun. It gathers an infinite range of different radiations from celestial space, of which visible light radiation forms an insignificant part.[33]

It should be stressed that Vernadskii's insight was significant in terms of both its scope and its overall intent and, at the same time, it was grounded on contemporary scientific understanding.[34] Given our familiarity with the biosphere concept, it is perhaps difficult to appreciate the importance of Vernadskii's work within its specific historical context. During the course of the last twenty years or so, a number of academics have attributed key innovations to Vernadskii's general insight and approach. For example, Vassoevich noted that Vernadskii was the first to approach the biosphere from a geochemical perspective,[35] and Yanshin drew attention to his importance in advancing the concept of 'living matter' in order to capture the global reach of organic life.[36] This point was developed by Sokolov, who highlighted Vernadskii's insight concerning humankind's role as a major geological force on a planetary scale.[37] Andrei Lapo suggested that Vernadskii's systematic focus on the biosphere as an entity worthy of study was in and of itself a key contribution of his work.[38] More specifically, he posited that Vernadskii provided the foundation for an appreciation of the Earth as a complex system.[39] And the

31 See Grinevald, op. cit. (11).

32 See, for example, Andrei G. Lapenis, 'Directed evolution of the biosphere: Biogeochemical selection or Gaia?', *Professional Geographer* (2002) 54, pp. 379–391; Jonathan D. Oldfield and Denis J.B. Shaw, 'V.I. Vernadsky and the noosphere concept: Russian understandings of society–nature interaction', *Geoforum* (2006) 37, pp. 145–154.

33 Vladimir I. Vernadskii, 'Biosfera', in *Biosfera i Noosfera*, Moscow: Rol'f, 2002, pp. 31–182, 35, emphases in the original (authors' translation).

34 See e.g. B.S. Sokolov, 'Vstupitel'noe slovo na simpoziume "V.I. Vernadskii i sovremennost'"', in B.S. Sokolov and A.L. Yanshin (eds.), *V.I. Vernadskii i sovremennost*', Moscow: Nauka, 1986, pp. 7–10, 8–9; A.L. Yanshin, 'V.I. Vernadskii i ego uchenie o biosfere i perekhoda ee v noosferu', in Sokolov and Yanshin, *V.I. Vernadskii i sovremennost'*, op. cit., pp. 28–40, 33; see also F.T. Yanshina and S.N. Zhidovinov, 'Predislovie', in V.I. Vernadskii, *Khimicheskoe stroenie biosfery zemli i ee okruzheniya*, Moscow: Nauka, 2001, pp. 5–12.

35 N.B. Vassoevich, 'Uchenie o biosfere (1802–1876–1926)', in A.L. Yanshin (ed.), *V.I. Vernadskii: Pro et Contra*, St Petersburg: Izdatel'stvo Russkogo Khristianskogo gumanitarnogo instituta, 2000, pp. 508–512, 509.

36 Yanshin, op. cit. (34), p. 33.

37 Sokolov, op. cit. (34), pp. 8–9.

38 A.V. Lapo, *Traces of Bygone Biospheres*, 2nd revised edn, Moscow: Mir Publishers, 1987, pp. 5, 12.

39 Lapo, op. cit. (38), pp. 23–24; see also Paul R. Samson and David Pitt (eds.), *The Biosphere and Noosphere Reader: Global Environment, Society and Change*, London: Routledge, 1999, p. 16.

Russian biologist Alexei Ghilarov, after listing a number of key features of Vernadskii's work, noted that the importance 'of these views is owing to their being combined in one conceptually coherent picture'.[40] Finally, Margulis *et al.*, in their foreword to the 1998 English-language edition of *The Biosphere*, highlighted three key 'empirical generalisations' which they felt captured the essence and significance of Vernadskii's work:[41] first, that from a cosmic perspective, the extent and range of living matter is limited to a relatively thin layer at the Earth's surface, and that the Earth is 'a self-contained sphere'; second, his belief in the ability of living matter fundamentally to influence geological features at the Earth's surface; and third, his observation that the spatial extent of the biosphere and related geochemical processes increase over time due to the expansion of life.

Vernadskii's 1926 book was divided into two distinct sections.[42] The first, entitled 'The Biosphere in the Cosmos' (*Biosfera v kosmose*), identified the biosphere as a complex phenomenon powered by the Sun and intimately connected with the Earth's geological processes. A key element of Vernadskii's insight was his assertion that, in essence, 'the biosphere may be regarded as an area of the Earth's crust occupied by transformers, converting cosmic radiations into active terrestrial energy – electrical, chemical, mechanical, thermal etc.'[43] In other words, he established a framework for conceptualizing living matter in its entirety as a key entity making use of the Sun's energy with the potential to rework the inorganic/non-living environment. Living matter was therefore conceptualized as a destabilizing entity within the context of the biosphere, giving rise to specific biogeochemical characteristics. Furthermore, he noted 'that a discontinuance of life would be inevitably linked with a cessation of chemical changes, if not with respect to all the Earth's crust then in any case its surface – the face of the Earth, the biosphere'.[44] The second part of the work ('The Domain of Life'/*Oblast' zhizni*) explored the extent and range of life within the biosphere from the deepest ocean to the upper reaches of the atmosphere. This analysis was important in determining the extent of overlap between the biosphere and the adjacent layers of the atmosphere, lithosphere and hydrosphere. It is in these areas of overlap, which Vernadskii considered technically part of the biosphere, that living matter is able to influence the chemical state of the different layers.

The movement of ideas

Alexey Ghilarov, writing in 1995, noted that Western science had, up to that point, largely ignored Vernadskii's ideas related to the biosphere. It is perhaps more accurate to say that direct and consistent engagement with his work had been relatively limited and this can be blamed to a large extent on the language barrier, as well as on the already

40 Ghilarov, op. cit. (16), p. 197.

41 Lynn Margulis, Mauro Ceruti, Stjepko Golubic *et al.*, 'Foreword to the English-language edition', in Vernadsky, op. cit. (11), pp. 14–19, 15.

42 For an English-language overview of this book see Smil, op. cit. (13), pp. 5–9.

43 Vernadskii, op. cit. (33), pp. 42–43 (authors' translation).

44 Vernadskii, op. cit. (33), p. 54 (authors' translation).

noted popularization of the biosphere concept during the 1970s which helped to dilute Vernadskii's intellectual legacy.[45] Additional obstacles undermining the effective dissemination of his ideas can be linked to a complex domestic situation. On the one hand, despite Vernadskii's sceptical stance towards the new Communist regime, he was tolerated by the Soviet Union's political apparatus due to a combination of factors, including the prestigious nature of his scientific work, his applied research and his evident patriotism.[46] On the other hand, Vernadskii's ideas were not always popular in the Soviet context and the consequent resistance to his work within the Soviet Union delayed the publication of certain volumes of work until some years after his death.[47] For example, during the 1930s his ideas concerning the biosphere and living matter were challenged publicly by a number of academics:

> From the perspective of Marxist philosophers [during the 1930s] [Vernadskii] was subjected to bitter critique. D. Novogrudksii, A.M. Deborin and A.A. Maksimov accused the scientist of vitalism, idealism and *bergsonism*;[48] regarded the disdain for the laws of dialectical materialism as intolerable; and demanded the prohibition of his work on living substances for being anti-Soviet.[49]

Vernadskii's work gained more positive reviews within the Soviet Union from the 1960s onwards, as evidenced by successive commemorative events such as a 1963 conference on the Chemistry of the Earth's Crust dedicated to the centenary of Vernadskii's birth,[50] a 1986 symposium entitled V.I. Vernadskii and the Present,[51] and a 1988 conference celebrating the 125th anniversary of his birth,[52] all of which testify to the growing importance attached to his intellectual legacy. More recently, as Yanshina and Zhidovinov have argued,[53] a key reason behind the later positive reassessment of his biosphere work rested on its relevance for the emerging environmental crisis.[54]

While the communication of Vernadskii's ideas concerning the biosphere to the West was undermined during the course of the twentieth century by both domestic and international barriers, he nevertheless managed to maintain a robust exchange of ideas with European colleagues during significant parts of his career. Much has been written

45 The situation has, however, changed during the course of the last twenty years or so, underpinned by the English-language translations of his key 1926 text *The Biosphere*. The first abridged version of his book was published in 1986 (Vladimir I. Vernadsky, *The Biosphere* (abridged version), Oracle, AZ: Synergetic Press, 1986) and this was followed by a full (albeit revised) translation in 1998 (Vernadsky, op. cit. (11)).

46 Bailes, op. cit. (23), pp. 160–178.

47 Bailes, op. cit. (23), p. 178.

48 This is a reference to the French philosopher Henri Bergson. According to Grinevald (op. cit. (11), pp. 25–26), Vernadskii's understanding of the biosphere as 'a biogeochemical evolving system with a cosmic significance . . . was indebted to many new and old ideas in science, as well as in philosophy, Bergson's anti-mechanistic epistemology of life notably'.

49 Yanshina and Zhidovinov, op. cit. (34), p. 10 (authors' translation).

50 *Khimiya zemnoi kory: Trudy Geokhimicheskoi konferentsii, posvyashchennoi stoletiyu so dnya rozhdeniya akademika V.I. Vernadskogo. Tom I*, Moscow: Izdatel'stvo Akademii Nauk SSSR, 1963.

51 Sokolov and Yanshin, *V.I. Vernadskii i sovremennost'*, op. cit. (34).

52 E.I. Kolchinskii (ed.), *V.I. Vernadskii i sovremennaya nauka*, Leningrad: 'Nauka' Leningradskoe otdelenie, 1988.

53 Yanshina and Zhidovinov, op. cit. (34), pp. 10–11.

54 See also Oldfield and Shaw, op. cit. (32).

in the Russian-language literature about the broad development of Vernadskii's ideas,[55] with more limited engagement in the Western literature,[56] and what emerges from this work is a sense of Vernadskii's openness to, and familiarity with, the key natural-science debates, discussions and intellectual legacies evident in Western Europe.[57] As intimated above, his ideas concerning the complex interaction between living and non-living nature, while influenced greatly by the work of Dokuchaev, had additional associations with the insight of earlier scientists such as Lamarck and Humboldt.[58] Indeed, the biographical work of Bailes highlights Vernadskii's early engagement with the writings of Humboldt as well as other major natural scientists such as Darwin before he even entered university.[59] Ghilarov, drawing from Nicolson's work on Alexander von Humboldt,[60] argues that Vernadskii's ideas can be usefully located within a slowly emerging understanding of nature shaped strongly by Kantian thought which shifted attention away from simply describing nature towards purposeful efforts to discern its inner workings.[61] Clearly, such a shift was predicated on the belief that nature was characterized by complex interactions between its constituent elements and that these interactions were of central importance to the character of the whole.[62] The early work of Lamarck appears particularly influential for Vernadskii with respect to his later writings,[63] and more specifically Lamarck's *Hydrogéologie* (1802),[64] which drew attention to the significance of living matter for the Earth's physical environment.

Further to his active engagement with European natural-science debate, Vernadskii's understanding and his associated research agendas were undoubtedly influenced by periods spent working abroad in Europe during both the late tsarist and the early Soviet periods.[65] As such, Vernadskii was not an unknown quantity beyond the Russian border. His reputation was further enhanced outside Russia via his association with the development of geochemistry, which gained prominence as a scientific discipline in the West primarily through the work of V.A. Goldschmidt.[66] In spite of this, the publication

55 Sokolov, op. cit. (34); Vassoevich, op. cit. (35); A.P. Vinogradov, 'Nauchnoe nasledstvo V.I. Vernadskogo', in *Khimiya zemnoi kory*, op. cit. (50), pp. 7–12; Yanshina and Zhidovinov, op. cit. (34), pp. 6–7.

56 For example, Bailes, op. cit. (23); Ghilarov, op. cit. (16); Alexei Ghilarov, 'Lamarck and the prehistory of ecology', *International Microbiology* (1998) 1, pp. 161–164; Grinevald, op. cit. (15); Oldfield and Shaw, op. cit. (32); Smil, op. cit. (13).

57 For example, see Ghilarov, op. cit. (16), pp. 199–200; Yanshin, op. cit. (34), pp. 29–30.

58 G.V. Gegamyan, 'Lamark, Vernadskii i biosferologiya', in Yanshin, op. cit. (35), pp. 513–519; Ghilarov, op. cit. (16); *idem*, op. cit. (56); Yanshin, op. cit. (34), p. 29.

59 Bailes, op. cit. (23), p. 13.

60 Nicolson, op. cit. (16), 1987.

61 Ghilarov, op. cit. (16), pp. 199–200.

62 For example, Ghilarov, op. cit. (56), p. 162.

63 Vernadskii, op. cit. (34), pp. 339–341; Vernadsky, op. cit. (21), p. 7; see also Hutchinson, op. cit. (12), p. 45.

64 J.B. Lamarck, *Hydrogeology* (tr. Albert V. Carozzi), Urbana: University of Illinois Press, 1964; see also Gegamyan, op. cit. (58); Ghilarov, op. cit. (56). For a general assessment see Albert V. Carozzi, 'Lamarck's theory of the earth: Hydrogeologie', *Isis* (1964) 55, pp. 293–307.

65 For example, Bailes, op. cit. (23); Yanshin, op. cit. (34), pp. 29–31.

66 Geochemistry emerged strongly in Russia via the activities of Vernadskii and his student A. Fersman during the early part of the twentieth century (for example, see A. Fersman, *Geochemistry for Everyone*,

during the 1920s of Vernadskii's work concerning the biosphere, in both Russian (1926) and French (1929), had a muted impact on the Western scientific community. Two conduits for his work in this area are, however, worthy of additional attention. The first relates to his professional links with the French scientists Pierre Teilhard de Chardin and Edouard Le Roy in connection with Vernadskii's sabbatical in Paris during the early 1920s. Indeed, his stay in France forms an important element of the story of the biosphere concept. Arriving in 1922 and remaining for approximately three years, during which time he spent a period lecturing at the Sorbonne, Vernadskii had the opportunity to pull together his ideas concerning geochemistry and the biosphere.[67] The resulting intellectual exchange between the three scientists proved productive and appears to have laid the foundations for Vernadskii's later work on the noosphere concept, a term he first encountered via Le Roy.[68] Vernadskii developed his interpretation of the noosphere idea during the 1930s, underpinned by a revision of his earlier work concerning living matter and arguing that both its form and its mass had changed over the course of evolutionary history.[69] For Vernadskii, the noosphere was conceptualized as a 'new stage of the biosphere's development' characterized by the emergence of humankind as a major geological force,[70] which was linked to the establishment of scientific thought as an instrumental agent of change.[71]

A second main conduit for Vernadskii's ideas concerned the ecologist George Evelyn Hutchinson.[72] Hutchinson was influential in facilitating the publication of two English-language versions of Vernadskii's work via collaboration with Vernadskii's son, George,[73] who had taken up a position in history at Yale during the late 1920s,[74] and with another Russian émigré at Yale, the invertebrate zoologist Alexander Petrunkevitch.[75] Hutchinson also championed Vernadskii's work relating to the

Moscow: Foreign Languages Publishing House, 1958), with concurrent and significant developments in Norway under V.A. Goldschmidt (1888–1947) and also in the USA (see Paul Rosbaud, 'Victor Moritz Goldschmidt (1888–1947)', *Applied Geochemistry* (1988) 3, pp. 361–369; Brian Mason, *Victor Moritz Goldschmidt: Father of Modern Geochemistry*, Special Publication No. 4, San Antonio, TX: The Geochemical Society, 1992). In contrast, the development of biogeochemistry was dominated by Vernadskii and his Russian school. G. Evelyn Hutchinson noted in his autobiography that his 1946 course on biogeochemistry was likely the first such course taught outside Russia. G. Evelyn Hutchinson, *The Kindly Fruits of the Earth: Recollections of an Embryo Ecologist*, New Haven: Yale University Press, 1979, p. 249.

67 Bailes, op. cit. (23), pp. 161–162.

68 See Samson and Pitt, op. cit. (39), pp. 60–70.

69 Yanshin, op. cit. (34), p. 35.

70 Yanshin, op. cit. (24), p. xxxii.

71 Vernadsky, op. cit. (21); see also Frank B. Salisbury (ed.), *Geochemistry and the Biosphere: Essays by V.I. Vernadsky*, Santa Fe, NM: Synergetic Press, 2007; Oldfield and Shaw, op. cit. (32).

72 See Gregory J. Cooper, *The Science of the Struggle for Existence: On the Foundations of Ecology*, Cambridge: Cambridge University Press, 2003, p. 63; Ghilarov, op. cit. (16), pp. 195–196; Polunin and Grinevald, op. cit. (11), p. 119.

73 These include V.I. Vernadsky, 'Problems of biogeochemistry, II', *Transactions of the Connecticut Academy of Arts & Sciences* (1944) 35, pp. 483–517; *idem*, op. cit. (21).

74 Joel B. Hagen, *An Entangled Bank: The Origins of Ecosystem Ecology*, New Brunswick: Rutgers University Press, 1992, p. 64.

75 Hutchinson, op. cit. (66), pp. 232–233.

biosphere in his own publications. For example, writing in the 1970 special issue of *Scientific American* on the biosphere, Hutchinson commented,

> The [biosphere] concept played little part in scientific thought, however, until the publication ... of two lectures by the Russian mineralogist Vladimir Ivanovitch Vernadsky. It is essentially Vernadsky's concept of the biosphere, developed about 50 years after Suess wrote, that we accept today.[76]

Hutchinson's awareness of Vernadskii's biogeochemical work would also provide an important link between post-war developments in ecology and biogeochemical interpretations of the biosphere concept, a point he drew attention to in his 1979 autobiography:

> Vernadsky had a strong influence on other aspects of my research [in addition to the chemical composition of living matter] ... Though I came to biogeochemistry through Vernadsky, I soon realized the great importance to biology of the concepts introduced by my father's friend Viktor M. Goldschmidt. Putting these two together in an ecological context I think did something to further the more chemical aspects of ecology.[77]

Furthermore, Hutchinson's work had added importance in the post-1945 period since he applied insights gained from the study of small-scale natural systems such as inland lakes to the global level, thereby supporting the view that the biosphere displayed similar characteristics to small-scale ecological systems and reinforcing the utility of the global conceptualization.[78] Hutchinson's efforts to disseminate Vernadskii's work amongst the English-speaking scientific community ensured that Vernadskii's ideas were at least acknowledged by ecologists during the post-war period. For example, Eugene Odum's highly influential 1953 textbook *Fundamentals of Ecology* made reference to Vernadskii's work concerning the biosphere and noosphere in the chapter dealing with 'Principles and concepts pertaining to the ecosystem and biogeochemical cycles'.[79]

Biogeochemical conceptualizations of nature and the rise of ecosystem ecology after 1945

This section reflects on the emergence in the West of an intellectual context that was receptive to biogeochemical understandings of the biosphere after 1945. More specifically, it focuses on the rise of ecosystem ecology during this period,[80] particularly in the US, underpinned by a growing belief amongst certain academics and policymakers in the potential of such science to address issues of resource management, as well as of the detrimental influence of humankind's activities on nature via the development of more advanced scientific understandings of natural systems.[81] Such initiatives would lay the

76 Hutchinson, op. cit. (12), p. 45.
77 Hutchinson, op. cit. (66), p. 233.
78 Hagen, op. cit. (74), p. 65.
79 Eugene P. Odum, *Fundamentals of Ecology*, Philadelphia: W.B. Saunders Company, 1953, pp. 9–23.
80 For example, Cooper, op. cit. (72), pp. 64–65.
81 See Worster, op. cit. (12), pp. 342–387.

foundations for the later Biosphere Conference and other key programmes of activity such as the International Biological Programme (see below), as well as linking effectively with the earlier substantive work of Vernadskii concerning the biosphere.

The development of ecosystem ecology in the West during the post-war period had its roots in the earlier work of ecologists such as Charles Elton, Hutchinson, Raymond Lindeman and Arthur Tansley.[82] Tansley's articulation of the ecosystem concept in 1935 was particularly significant and was prompted at least in part by a desire to resist the overt organismal interpretations of plant communities associated with the work of Frederic Clements.[83] More specifically, the abstract ecosystem concept which Tansley advanced acknowledged the difficulty of determining geographically fixed ecological entities and as such was conceived as a flexible means for establishing an analytical focus in ecological studies.[84] Tansley's approach recognized the importance of focusing attention on the interaction between both the living and non-living environment in order to comprehend the complex exchanges of energy and matter characterizing a given ecological system.[85]

Raymond L. Lindeman is considered a pivotal figure helping to advance biogeochemical understandings of the ecosystem concept and thus acknowledging the limitations of focusing predominantly on the living environment.[86] His 1942 paper 'The trophic-dynamic aspect of ecology' employed the ecosystem concept as a means for exploring the associated flows of energy and matter through a defined area.[87] Lindeman was influenced strongly by the ideas of Hutchinson and the last year of his short life was spent working with Hutchinson at Yale. Lindeman's association with Hutchinson undoubtedly reinforced the utility of Vernadskii's biogeochemical work and reference to his ideas was evident in Lindeman's seminal 1942 paper:

> The trophic-dynamic viewpoint, as adopted in this paper, emphasizes the relationship of trophic or 'energy-availing' relationships within the community-unit to the process of succession. From this viewpoint, which is closely allied to Vernadsky's 'biogeochemical' approach . . . and to the 'oekologische Sicht' of Friederichs . . . a lake is considered as a primary ecological unit in its own right . . . Upon further consideration of the trophic cycle, the discrimination between living organisms as parts of the 'biotic community' and dead organisms and inorganic nutritives as parts of the 'environment' seems arbitrary and unnatural.[88]

82 For detailed overviews see Hagen, op. cit. (74); Frank Benjamin Golley, *A History of the Ecosystem Concept in Ecology: More than the Sum of the Parts*, New Haven: Yale University Press, 1993; Worster, op. cit. (12).

83 Hagen, op. cit. (74), p. 83; see also Cooper, op. cit. (72), p. 62.

84 Stephen Trudgill, 'Classics in physical geography revisited: Tansley, A.G. 1935: The use and abuse of vegetational concepts and terms. Ecology 16, 284–307', *Progress in Physical Geography* (2007) 31(5), pp. 517–522, 520–521.

85 Golley, op. cit. (82), p. 24. For a discussion of the intellectual history underpinning Tansley's concept see Kurt Jax, 'Holocoen and ecosystem: on the origin and historical consequences of two concepts', *Journal of the History of Biology* (1998) 31, pp. 113–142, 113–115.

86 Martin Kent, 'Classics in physical geography revisited: Lindeman, R.L. 1942: The trophic-dynamic aspect of ecology, Ecology 23, 399–418', *Progress in Physical Geography* (2000) 24(2), pp. 253–260, 257.

87 Raymond L. Lindeman, 'The trophic-dynamic aspect of ecology', *Ecology* (1942) 23(4), pp. 399–418; see also Hagen, op. cit. (74), pp. 87–99.

88 Lindeman, op. cit. (87), p. 399.

The International Biological Programme (1964–1974) and the strengthening of ecosystem science

As noted above, the post-1945 period was characterized by an emerging concern over resource use and the detrimental influence of humankind on nature, and this helped to raise the profile of ecosystem ecology, a trend that was particularly noticeable in the United States. Importantly, an ecosystem approach found clear expression and further support in the activities of the influential International Biological Programme (IBP), which had its intellectual origins in the late 1950s and ran formally over the period from 1964 to 1974.[89] Due to its considerable overlap with the focus of the planned 1968 Biosphere Conference, the work of the IBP also played a significant role in the scientific preparations for this conference, of which more below.[90]

The IBP emerged in the aftermath of the 1957–1958 International Geophysical Year (IGY),[91] and is credited to the initiative of Sir Rudolph Peters, Giuseppe Montalenti and Lloyd Berkner, as well as Conway H. Waddington.[92] The IBP was a complex and wide-ranging programme incorporating thousands of scientists from around the globe.[93] The fundamental focus of the programme was concerned with issues of biological productivity and with human adaptability to ongoing changes in the natural environment. Writing in 1975, the scientific director of the IBP, E.B. Worthington, noted,

> the subject of IBP was defined as 'The Biological Basis of Productivity and Human Welfare'. Its objective was to ensure the worldwide study of (a) organic production on the land, in fresh waters, and in the seas, and the potentialities and uses of new as well as of existing natural resources, and (b) human adaptability to changing conditions.[94]

It should be recognized that the programme's subsequent bias towards ecosystem studies, particularly within the 'Productivity Terrestrial' section of its activity, was by no means a foregone conclusion. However, the US-based element of the initiative moved strongly in that direction and over time appears to have exerted a marked influence over the programme more generally.[95] Kwa provides a detailed account of the US involvement with a specific focus on the reasons behind the national programme's

89 See Golley, op. cit. (82), pp. 109–140; Chunglin Kwa, 'Representations of nature mediating between ecology and science policy: the case of the International Biological Programme', *Social Studies of Science* (1987) 17, pp. 413–442; E. Barton Worthington, *The Ecological Century: A Personal Appraisal*, Oxford: Clarendon Press, 1983, pp. 160–177.

90 Jean G. Baer, 'The International Biological Programme', *Nature and Resources* (1967) 3(4), pp. 1–3.

91 For an overview of the IGY see Christy Collis and Klaus Dodds, 'Assault on the unknown: the historical and political geographies of the International Geophysical Year (1957–8)', *Journal of Historical Geography* (2008) 34, pp. 555–573.

92 See E.B. Worthington (ed.), *The Evolution of IBP*, Cambridge: Cambridge University Press, 1975.

93 See Golley, op. cit. (82), pp. 109–140; Worthington, op. cit. (89); *idem*, op. cit. (92). The activities of the IBP were divided into seven 'sections' and included (i) Productivity terrestrial, (ii) Production processes, (iii) Conservation terrestrial, (iv) Productivity freshwater, (v) Productivity marine, (vi) Human adaptability, and (vii) Use and management of resources. See Worthington, op. cit. (92).

94 Worthington, op. cit. (92), p. 18.

95 For example, see Golley, op. cit. (82), pp. 115–140.

ultimate bias towards ecosystem ecology in spite of the relatively weak institutional position of ecology in the US education system during the early post-war period.[96] Central to Kwa's argument is the role played by basic understandings of nature circulating within both scientific and lay communities at that time, with the suggestion that they were underpinned by the general metaphor of the 'cybernetic machine'. In other words, there was a broadly shared notion that natural systems were ultimately 'knowable' and that the resulting knowledge would facilitate the effective management of these systems. As Kwa notes,

> Apparently, the representation of nature as a machine to be controlled was dominant in the period immediately before and after 1970. This shared representation of nature made possible a shared conception of how environmental problems were to be defined, and how their solution should be envisaged. This made cybernetic-systems ecology appear as the natural candidate to do the job. The only thing needed was a crash programme which would make the concepts of systems ecology operational. The IBP would, it was hoped, provide this.[97]

As a consequence both of this shared conceptualization of how natural systems function, and of a general appreciation of the need to address resource management and environmental pollution issues, ecosystem science in the US received millions of dollars of funding during the late 1960s and early 1970s.[98]

In reviewing the IBP more broadly in 1983, Worthington noted,

> It was in the study of ecosystems, incorporating not only the biological disciplines but also the chemistry and physics of the environment, that the IBP broke much new ground. The atmosphere, the hydrosphere, the biosphere, and the lithosphere were all in the picture.[99]

He went on to suggest that the 'application of "system analysis" to biological systems was one of the main innovations developed during the IBP'. The IBP thus provided a clear indication of the growing importance placed on an ecosystem approach at the international level in order to address prevailing natural-resource management and pollution concerns during the 1960s. It was within this intellectual climate that the 1968 Biosphere Conference was conceived and it is to this event that we now turn.

1968 UNESCO Biosphere Conference

The Biosphere Conference represented an event of some significance in the context of the developing global environmental agenda during the 1960s.

In addition to its close collaboration with the IBP, the conference involved a range of organizations under the UN umbrella as well as the International Union for Conservation of Nature and Natural Resources (IUCN). In total it attracted 238 delegates from sixty-three member states and a large number of delegates from international organizations. Its main objective was 'to show how the modern scientific

96 Kwa, op. cit. (89).
97 Kwa, op. cit. (89), p. 433.
98 For example, see Golley, op. cit. (82), pp. 131–132.
99 Worthington, op. cit. (89), p. 170.

approach can help in defining rational methods of utilization of the environment while at the same time achieving the goals of conservation. In this view, conservation itself becomes a part of rational use'.[100]

For our purposes, two features of the preparatory period underpinning the conference are worthy of particular note: first, the influence of the Soviet soil scientist Victor A. Kovda within UNESCO in relation to the articulation and advancement of Vernadskii's work related to the biosphere; second, a growing consensus within UNESCO, allied to broader trends within the Western natural-scientific community, over the relevance of ecological approaches for addressing issues of natural-resource use, thus providing a context conducive to a broad acceptance of a biogeochemical understanding of the biosphere concept.

Victor A. Kovda (1904–1991) and the Advisory Committee on Natural Resources Research

Victor Kovda was director of UNESCO's Natural Sciences Department from 1959 to 1964, having developed a significant reputation in the area of soil science prior to his appointment, with a particular specialism in the soils of arid and desert regions.[101] He would gravitate towards an interest in the broader concept of the biosphere during the latter part of his life.[102] Importantly, from the perspective of this paper, Kovda had been schooled in the Dokuchaevian soil-science tradition via the influence of B.B. Polynov, who had himself been one of Dokuchaev's students,[103] and this undoubtedly encouraged his appreciation of Vernadskii's work concerning the biosphere.[104] In addition to his links with UNESCO, over the course of his professional career Kovda served on a variety of international and high-ranking Soviet committees devoted to soils, resource use and related environmental issues.[105] The combination of Kovda's position at UNESCO, his intellectual background and status within the Soviet Union,[106] and his role in a number of international scientific initiatives ensured that he was well placed to promote the ideas of Vernadskii concerning the biosphere when the opportunity arose during the preparatory period underpinning the conference.

100 Anon., 'Conference on the resources of the biosphere', *Nature and Resources* (1967) 3(2), pp. 1–3, 1.

101 E.g. G.V. Dobrovolsky and V.I. Kefeli, 'In memoriam: Prof. Dr Victor A. Kovda (1904–1991)', *Bulletin of the International Society of Soil Science* (1991–1992) 80, pp. 77–78; G.V. Dobrovol'skii, 'Osnovatel' ucheniya o roli pochvy v stanovlenii i razvitii biosfery', in *idem* (ed.), *V.A. Kovda: Zhizn' i nauchnoe nasledie k 100-letiyu so dnya rozhdeniya*, Moscow: Nauka, 2004, pp. 6–16.

102 For example, Kovda, op. cit. (12); see also Dobrovol'skii, 'Osnovatel' ucheniya o roli pochvy v stanovlenii i razvitii biosfery', op. cit. (101); Dan H. Yaalon, 'V.A. Kovda – meetings with a great and unique man', *HPSSS Newsletter* (February 2004) 11, pp. 4–9, 8.

103 John A.C. Fortescue, 'Landscape geochemistry: retrospect and prospect – 1990', *Applied Geochemistry* (1992) 7, pp. 1–53, 6.

104 Kovda also played a role along with other students of Polynov (in particular A.I. Perel'man and M.A. Glazovskaya), in helping to develop the field of landscape geochemistry, with its aim of understanding chemical movements within the context of defined landscape regions. Fortescue, op. cit. (103), pp. 8–10.

105 Dobrovol'skii, *V.A. Kovda: Zhizn' i*, op. cit. (101), pp. 215–218.

106 Vera A. Dmitrieva and Nicholas Polunin, 'Victor Abramovich Kovda, 1904–91', *Environmental Conservation* (1992) 19, pp. 364–365; Yaalon, op. cit. (102), p. 5 n. 3.

A main organizational impetus for the 1968 Biosphere Conference was linked to the work of the UNESCO Advisory Committee on Natural Resources Research (ACNRR), which had its first meeting in 1965.[107] The committee was populated by fifteen leading international experts and this included the aforementioned Kovda. The ACNRR provided strategic guidance to the Division of Studies and Research relating to Natural Resources which was situated within the Natural Sciences Department/Section of UNESCO and led by Michel Batisse.[108] More generally, the committee was responsible 'for advising the Director-General [of UNESCO] on the preparation of UNESCO's programmes for the promotion of research and training in the geological, hydrological, soil and ecological sciences, as well as for the study and conservation of natural resources'.[109] It would appear that the scientific origins of the Biosphere Conference lay primarily with the activities of the ACNRR.[110] Michel Batisse, in a reflective piece exploring Kovda's professional contribution to UNESCO over the course of many years, indicates that Kovda made explicit use of Vernadskii's biosphere concept during the work of the committee and, furthermore, following the committee's recommendation for an interdisciplinary conference, proposed the theme of the 'rational use and protection of the biosphere's resources'.[111] More generally, the final report from the inaugural meeting of the ACNRR held in 1965 drew attention to the growing dominance of an ecological approach within UNESCO at that time:

> Interdisciplinary activities relating to ecology and conservation have, from the Committee's point of view, primary importance among projects submitted for its consideration. These activities, which consider nature as a whole, are in fact a particularly propitious field of action for Unesco, since there is perhaps no scientific organization which could ensure the participation of all the specialists necessary for their execution.[112]

Thus the committee's support for a broad ecological approach formed part of a much wider initiative within UNESCO. A review of existing work concerning the study and assessment of natural resources at the international level and also with specific reference to the natural-resources work programme of UNESCO was carried out by the organization in the mid-1960s in order to determine best practice. This resulted in the identification of four key approaches which it was felt would assist in the effective study

107 From an organizational perspective, the Advisory Committee on Natural Resources Research replaced and expanded the activities of the former Arid Zone and Humid Tropics Committees. See UNESCO, *Unesco's Natural Resources Research Programme*, UNESCO/AVS/NR/118, 26 February 1965, p. 7.

108 Malcolm Hadley, 'Nature to the fore: the early years of UNESCO's environmental programme, 1945–1965', in Patrick Petitjean, Vladimir Zharov, Gisbert Glaser *et al.* (eds.), *Sixty Years of Science at UNESCO 1945–2005*, Paris: UNESCO, 2006, pp. 201–232, 224–225. Michel Batisse was a key figure in UNESCO's natural resources programme and would act as general secretary of the Biosphere Conference.

109 Article 2.1, Statutes of the Advisory Committee on Natural Resources Research. Statutes of the Advisory Committee on Natural Resources Research are listed in the Appendix of the *Resolutions and Decisions Adopted by the Executive Board at Its Seventieth Session*, Paris, 4 June 1965, available at http://unesdoc.unesco.org/images/0011/001132/113213e.pdf, accessed 8 October 2010.

110 Anon., op. cit. (100), p. 1.

111 Michel Batisse, 'Rabota v YuNESKO', Dobrovol'skii, op. cit. (101), pp. 60–66, 65.

112 UNESCO, Advisory committee on natural resources research, first session: Final Report, *UNESCO/NS/201*, 3 December 1965, p. 5.

of the natural environment and its associated resources.[113] These included an 'ecological approach', an 'integrated approach', a 'conservation approach' and so-called 'model studies'. The emphasis on modelling natural systems via a focus on the complex interactions between living and non-living matter was clear to see in the associated documentation:

> Once understood, even partially, the behaviour of the interrelated variables provides a sounder basis for scientific judgement than information gained solely from single-factor investigations ... [a] truly ecological approach must obviously aim at perceiving the interaction of organisms with inorganic phenomena, a fact which clearly demonstrates the magnitude of the obstacles barring the way to a comprehensive understanding of nature. Nevertheless, in an age when man [*sic*] is more capable than ever of altering the conditions of his environment, such attempts at comprehensive understanding must be made so that, as much as possible, change be introduced with the help of nature rather than the opposition. It is in the search for a sound conservation approach that this endeavour finds its best reflection.[114]

As preparations for the conference gathered pace, efforts were made to pool current scientific understanding pertaining to the twin foci of natural-resource use and conservation. These included collaborative initiatives between various UN organizations and related bodies. For example, Raymond F. Dasmann was asked by UNESCO to prepare a paper on the general theme of 'Conservation and rational use of the environment'.[115] Dasmann's initial draft was developed further with inputs from the Food and Agricultural Organization (FAO), the World Health Organization (WHO) and other specialists in order to smooth its passage through the UNESCO bureaucracy.[116] The preamble to a summarized version of the report relayed in UNESCO's *Nature and Resources* journal indicated that the paper would serve as a reference point for the planned 1968 conference. The summarized version went on to state,

> This problem [preservation of the environment] is vital today when the size of an increasing world population exerts ever greater pressure on the environment, threatening it with irreparable damage and loss in its utilization potential. The latter must be respected at all costs. Such an attitude in no way implies conflict between the maintenance of the production capital represented by the natural environment and its intensive exploitation by man [*sic*]. If such were the case, production would have to be curtailed, whereas, on the contrary, an increase is absolutely essential. Conservation of the natural environment must therefore be dynamic and not static. It implies that the potential of the environment must be respected in any exploitation, which must therefore be 'rational'.[117]

113 UNESCO, Natural resources research and the Unesco programme, Advisory committee on natural resources research, first session (23–25 September), UNESCO/AVS/NR/171, 23 August 1965, pp. 2–4.

114 UNESCO, op. cit. (113), p. 3.

115 Anon., 'Conservation and rational use of the environment', *Nature and Resources* (1968) 4(2), pp. 2–5, 2. Dasmann was at that time a senior associate at the Conservation Foundation in Washington, DC and would go on to play a role in the establishment of UNESCO's Man and Biosphere (MAB) programme. See Raymond F. Dasmann, *Called by the Wild: The Autobiography of a Conservationist*, Berkeley: University of California Press, 2002, pp. 139–141.

116 Dasmann, op. cit. (115), pp. 140–141.

117 Anon., op. cit. (115), p. 2.

The Biosphere Conference

Following the recommendation of the ACNRR, a Preparatory Committee for the Biosphere Conference was established which met on two occasions, during March 1967 and January 1968. It has not been possible to determine the precise membership of this committee (although it seems likely to have been populated to a large extent by members of the ACNRR); nevertheless, Michel Batisse makes clear the central importance of Kovda during this preparatory period.[118] The first meeting of the Preparatory Committee identified the need for a series of review papers and working documents concerning, amongst other things, the 'current state of scientific knowledge and identification of major deficiencies'.[119] The second meeting provided more details of these review papers (see Table 1) and outlined the intention to include a paper on the 'Scientific concepts relating to the biosphere'.[120] It was Kovda who was subsequently tasked with authoring this particular background paper.

The version of Kovda's review paper ('Contemporary scientific concepts relating to the biosphere') published in the conference proceedings was embellished with comments and additions by four other scientists as well as by the Secretariats of UNESCO and the FAO.[121] It drew heavily from the biogeochemical tradition pioneered by Vernadskii. Both the Russian edition of Vernadskii's 1926 publication *The Biosphere* and his later work, *The Problems of Biogeochemistry* (1934), were cited in the paper.[122] More broadly, the ideas conveyed by Kovda in the paper echoed those found in the Soviet Union's official report to the conference, which had been prepared under the editorship of I.P. Gerasimov (who was at that time director of the Institute of Geography, Soviet Academy of Sciences) and included the work of Kovda as well as a host of other Soviet academics.[123]

Kovda's paper began with an analysis of the general concept of the biosphere before moving on to discuss its underlying biogeochemical functions. Focusing on the introduction and first section of this paper (entitled 'The biosphere of the planet Earth and its peculiarities'), a range of key conceptual points can be identified which resonate clearly with the overarching framework outlined by Vernadskii. First, the biosphere of the Earth was placed within an evolutionary framework and established as 'an ancient, extremely complex, multiple, all-planetary, thermodynamically open, self-controlling system of living matter and dead substance, which accumulates and redistributes immense resources of energy and determines the composition and dynamics of the

118 Batisse, op. cit. (111), p. 65.

119 Anon., op. cit. (100), p. 2.

120 Anon., 'Conference on the resources of the biosphere', *Nature and Resources* (1968) 4(1), pp. 2–3, 2.

121 The Russian-language version of this paper was published in a collection of essays as follows: V.A. Kovda (ed.), *Biosfera i ee resursy*, Moscow: Nauka, 1971.

122 Vladimir I. Vernadskii, *Problems of Biogeochemistry. Part I: Significance of Biogeochemistry for Studying the Biosphere*, Leningrad: Izdatel'stvo Akademii Nauk SSSR, 1934.

123 I.P. Gerasimov (ed.), *Resources of the Biosphere on the Territory of the USSR: Scientific Principles of Rational Use and Conservation. National Report for the International Conference on the Resources of the Biosphere, UNESCO, 1968*, Moscow: State Committee of the USSR Council of Ministers for Science and Technology, 1968.

Table 1. *Background papers presented at the 1968 Biosphere Conference. Compiled by the authors from UNESCO,* Use and Conservation of the Biosphere: Proceedings of the Intergovernmental Conference of Experts on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere, Paris 4–13 September 1968, *UNESCO: Paris, 1970*

Background papers	Authors of original draft paper (bold) and subsequent comments and additions (*italics*)
Contemporary scientific concepts relating to the biosphere	**Prof. V. Kovda and collaborators (USSR)** *Prof. Frederick Smith (USA), Prof. F.E. Eckardt (Denmark), Dr M. Hadley (UK), Dr E. Bernard (Belgium) and the Secretariats of UNESCO and FAO*
Impacts of man on the biosphere	**Dr F. Fraser Darling (UK)** *Prof. Vladimir Sokolov (USSR), Prof. Frederick Smith (USA), Prof. François Bourlière (France) and the Secretariats of UNESCO and FAO*
Soils and the maintenance of their fertility as factors affecting the choice of use of land	**Prof. G. Aubert (France)** *Dr F. Fournier (France), Dr V. Rozanov (USSR) and the Secretariats of UNESCO and FAO*
Water resources problems: present and future requirements for life	**Dr H.C. Pereira (UK)** *Dr S. Dimitrescu (Romania), Dr H.L. Penman (UK), Dr K. Szesztay (Hungary), Dr J. Nemeč (Czechoslovakia), Dr R.L. Nace (USA) and the Secretariats of UNESCO, WHO and FAO*
Scientific basis for the conservation of non-oceanic living aquatic resources	**Department of Fisheries of FAO (Dr William A. Dill and Dr T.V.R. Pillay)** *Prof. A.E. Bonetto (Argentina), K. Kuronuma (Japan), J. Lemasson (France), H. Sioli (FRG), R.H. Stroud (USA), G. Svärdson (Sweden) and E.B. Worthington (UK) and the Secretariats of UNESCO, WHO and FAO*
Natural vegetation and its management for rational land use	**Prof. H. Ellenberg (FRG) and Prof. J. Lebrun (Belgium)** *Secretariats of UNESCO and FAO*
Animal ecology, animal husbandry and effective wildlife management	**Prof. Derek Tribe (Australia)** *Dr K. Curry-Lindahl (Sweden), Dr J. Pagot (France), Dr V. Sokolov (USSR), Dr F. Smith (USA) and the Secretariats of UNESCO, WHO and FAO*
Preservation of natural areas and ecosystems; protection of rare and endangered species	**Prof. Stanley A. Cain (USA)** *Prof. V. Sokolov (USSR), Prof. Frederick Smith (USA), Prof. K. Curry-Lindahl (Sweden), Prof. José Candido de Melo Carvalho (Brazil), Sir O. Frankel (Australia), Mr P. Scott (UK) and the Secretariats of UNESCO and FAO*
Problems of deterioration of the environment	**Draft entrusted to the WHO and prepared by Dr Abel Wolman (USA) with specific contributions on air pollution by Prof. L.T. Friberg (Sweden) and on soil pollution by Prof. H. Shuval (Israel)** *Secretariats of UNESCO and FAO*
Man and his ecosystems; the aim of achieving a dynamic balance with the environment, satisfying physical, economic, social and spiritual needs	**Prof. René Dubos (USA)** *Prof. Marion Clawson (USA), F. Fraser Darling (UK), F. Bourlière (France) and the Secretariats of UNESCO, WHO and FAO*

Earth's crust, atmosphere and hydrosphere'.[124] Second, the paper retained Vernadskii's concept of 'living matter' as inclusive of the totality of organisms on the planet. Related to this, it outlined Vernadskii's understanding of the key components of the biosphere, the aforementioned 'living matter', 'biogenic matter' (formed via the activity of living matter, e.g. coal, soil humus and so on), and 'biocosnic matter' or bioinert matter, from the Russian *biokosnoe veshchestvo* (resulting from the interaction of both living and non-living matter and including water, soil and so on).[125] Third, the paper highlighted the structural units comprising the biosphere. This section drew predominantly from the work of the Russian geobotanist V.N. Sukachev who, as noted above, was also influenced by the Dokuchaevian tradition and was a keen follower of the Vernadskian school of thought.[126] The paper moved on to define the biosphere as 'the highest level of the organization of living matter on the Earth'.[127] Fourth, the section ended by underlining the considerable benefits for humankind's ability to manage and conserve the Earth's natural systems to be derived from a more scientific understanding of how the biosphere functions. The emphasis on science and the rational application of science was a cornerstone of Vernadskii's overarching framework and, indeed, remains at the heart of the contemporary international drive towards sustainable development.

The published Final Report of the conference maintained the link with Vernadskii's general approach to the biosphere, reflecting broad agreement with the main principles laid out in Kovda's review paper.[128] More specifically, the general conclusion to this report stated,

> it was recognized [at the conference] that the biosphere is that thin shell at the interface of the atmosphere, hydrosphere and lithosphere where life and its products exist; that living organisms manifest their characteristics by constant interrelations with the environment; and that in doing so the interactions themselves create a degree of systematic order . . . the biosphere is seen to occur as an array of ecosystems or levels of organization of life and environment according to various patterns of occurrence of kinds of organisms and sets of physical-chemical conditions of the environment.[129]

Concluding remarks

In this paper we have traced the emergence and subsequent dissemination of a biogeochemical understanding of the biosphere from late nineteenth-century Russia to the 1968 Biosphere Conference in Paris, recognizing the relevance of the biosphere

124 Victor Kovda *et al.*, 'Contemporary scientific concepts relating to the biosphere', in UNESCO, *Use and Conservation of the Biosphere: Proceedings of the Intergovernmental Conference of Experts on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere, Paris 4–13 September 1968*, Paris: UNESCO, 1970, pp. 13–29, 15.

125 Vernadskii also referred to 'inert matter' (*kosnoe veshchestvo*), which is formed in the absence of living matter. See Vernadskii, op. cit. (63), pp. 70–71; see also Ghilarov, op. cit. (16), p. 196.

126 For example, see Douglas R. Weiner, *A Little Corner of Freedom: Russian Nature Protection from Stalin to Gorbachëv*, Berkeley: University of California Press, 1999, pp. 387–389.

127 Kovda *et al.*, op. cit. (124), p. 17.

128 UNESCO, op. cit. (124), pp. 194–195.

129 UNESCO, op. cit. (124), p. 234.

concept for the development of scientific and policy agendas concerning the effective management of natural resources and mitigation of the environmental consequences of human activity during the second half of the twentieth century. While acknowledging the long-standing and complex strands of thought underpinning the biosphere concept, particular emphasis has been placed on the work of the Russian biogeochemist Vladimir Ivanovich Vernadskii.

In order to aid the analysis, four specific moments in the development and subsequent dissemination of a biogeochemical understanding of the biosphere were explored. At an abstract level, these draw attention to the various ways in which scientific knowledge is shaped, disseminated and transmitted through time as well as from place to place. What becomes evident through the course of the analysis is the complexity of such processes and the sometimes arbitrary manner in which particular scientific understandings can be advanced and propagated. For example, in this case, contextual factors played a key role at different points in the narrative. Most obviously, Vernadskii's early scientific career at St Petersburg University during the late nineteenth century engendered within his work a deep appreciation of the complex interaction between living and non-living entities. Such insight would form an important element of Vernadskii's later development of biogeochemistry as a distinct discipline, as well as his broader conceptualization of the biosphere. Some fifty years later, the growing consensus in the West concerning the need to address emerging natural-resource use and pollution concerns, combined with the emergence of ecosystem thinking as the most appropriate means to address such concerns, particularly in the United States, provided an intellectual environment amenable to Vernadskii's biogeochemical approach to the biosphere.

A further factor helping to ease acceptance of Vernadskii's ideas during the interwar and early post-war years was a general awareness of his activities concerning the development of biogeochemistry within sections of the Western scientific community, a factor which also hints at a certain level of mobility with respect to Vernadskii's work in spite of the prevailing language and ideological barriers. Nevertheless, as highlighted above, this movement was a protracted affair and far from comprehensive in nature. In part facilitated by Vernadskii's ability and willingness to travel in Western Europe during the late tsarist and early Soviet periods, two main conduits for the transmission of his ideas were highlighted. The first was related to his stay in Paris during the early 1920s and his significant discussions with Pierre Teilhard de Chardin and Edouard Le Roy. The second was associated with the activities of the ecologist George Evelyn Hutchinson. Crucially, Hutchinson would play an influential role in the early development of ecosystem ecology and as such his active promotion of Vernadskii's work had added value in introducing the English-speaking scientific community to the relevance of Vernadskii's ideas and conceptual framework.

However, the combination of an amenable scientific and policy environment, and a general awareness of Vernadskii's work within the emerging community of ecosystem scientists in the West, while effective in helping to raise the profile of Vernadskii, still fails to explain the apparent prominence of his work at the 1968 Biosphere Conference. We have argued that this occurrence, whilst undoubtedly facilitated by the processes highlighted above, was nevertheless more the product of chance and the fortuitous presence of an influential Soviet academic, steeped in the same intellectual background as Vernadskii, within the upper echelons of UNESCO. Victor Kovda's influential role in the preparatory work underpinning the Biosphere Conference, in addition to his direct utilization and referencing of Vernadskii's work in his conference paper, helped disseminate the latter's ideas widely amongst the gathered scientists and organizational representatives. This single and relatively efficient act of dissemination contrasts markedly with the long, drawn-out process of dissemination of Vernadskii's biosphere concept following the publication of his book in 1926, and further highlights the often bumpy, as well as unpredictable, path scientific ideas must follow in order to gain a certain level of acceptance and acknowledgement.