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The Evolution of the Anthroposphere

Historicizing Geoanthropology

by
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Historicizing Geoanthropology *

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After briefly introducing the ongoing debate about the Anthropocene from an interdisciplinary point of view—with a focus on the lack of common ground among different scholarly communities in addressing the Anthropocene as a geo-cultural notion—the article attempts to frame geoanthropology as a novel interdisciplinary approach that can help overcome tensions between the sciences and the humanities. It does so by providing two examples of geoanthropological investigation: first, the experimental project Anthropogenic Markers*; second, an attempt to historicize geoanthropology through the exploration of historical efforts to perceive nature as integrated with humanity. The first case,* Anthropogenic Markers*, shows some of the historical contexts, epistemic settings, and conceptual contributions of Anthropocene geology, thus exploring ways of combining the anthroposphere and the geosphere without losing sight of the different local and political contexts. The second case introduces the concept of 'epistemic evolution', crucial to understanding geoanthropology from a historical perspective, and combines it with the notion of the 'noosphere', particularly in the elaboration provided by Russian geochemist Vladimir I. Vernadsky. The noosphere is described as a new phase of biosphere evolution in which humans have become aware of their ability to reshape the Earth, especially through the invention of modern technologies. In this respect, the noosphere is characterized by the emergence of a new awareness that integrates cultural and geological forms of agency in their epistemic and co-evolutionary aspects. The noosphere appears as a global process oriented towards understanding the world as an integrated system, which is a precondition for any attempt to rematerialize and rebalance the role of humanity in the Earth System.*

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1. Lack of interdisciplinarity in the Anthropocene debate

More than ever in the history of scientific research, the theory of the Anthropocene calls for the collaboration of sciences and the humanities. Previous attempts were not sufficiently long-lived to equal the richness and polyphony of the Anthropocene debate of recent years. To mention a prominent case, mid-20th-century cybernetics was launched under the banner of interdisciplinarity, with the *Macy conferences* bringing together a striking variety of scholars to discuss communication across disciplines. However, despite the rich variety, cybernetics soon became assimilated into computer science and information theory, while logical reasoning became the primary tool in the study of self-regulating systems in animals and machines[1].

Over the past decade, the Anthropocene debate has been so widespread and pervasive as to become an almost unprecedented case of cross-contamination between sciences and the humanities. This is probably due to the very nature of its object of study. Anthropocene scholars point to the fact that the Earth and its biogeochemical processes are changing irreversibly under the unbearable effect of human activities and that these effects are archived in the geology of the Earth, in its rocks and strata. The concept cannot be understood without referring to the deep interrelation between human societies and the natural systems with and in which they co-evolved. Hence, its understanding rests in the interstitial space between the study of the *anthroposphere* (the sphere where humans stand out as the main actors and shapers of the biosphere's appearance and functioning) and the *geospheres* that constitute the Earth System (atmosphere,

[1] The field of the humanities has lost terrain, except for some branches of social sciences and psychology that apply game theory and agent-based models to the study of control mechanisms in animals and machines. See for example Gordin et al. 2013.

biosphere, hydrosphere, lithosphere, and cryosphere). In this sense, the Anthropocene does not belong to any exclusive discipline or realm: it is a boundary object *par excellence* (Selcer 2021). Yet, its meaning is strikingly straightforward (Zalasiewicz 2022).

This plurality makes for a perfect experimental work on the practice of interdisciplinarity, favoring cross-collaborations and the hybridization of research and methods. Indeed, if humans are responsible for pressuring the Earth beyond its capacity, exposing themselves and many other species to unprecedented risks, then the humanities and social sciences are necessarily entitled to join the discussion, share concerns and advance interpretations about the origins of the environmental crisis and how to address it at a regulatory level. Dipesh Chakrabarty's influential essay, *The Climate of History. Four Theses,* underscores how the Anthropocene could trigger a wide interdisciplinary conversation and might even lead to a renewal and redefinition of history (Chakrabarty 2009), while Helmuth Trischler points out that since the Anthropocene is as much a geological as a cultural concept, the adoption of an interdisciplinary framework is the only viable strategy to effectively understand and mitigate the broad range of consequences of human activities on the global environment and recalibrate our production system as well as our social and cultural values (Trischler 2016).

Although the Anthropocene literature recognizes the importance of linking different approaches in a multidisciplinary perspective[1], scholarly communities still appear hesitant to bridge the gap between the different ways of interpreting and conveying the Anthropocene. The debate is generally characterized by a tendency to counterpose, rather than bringing together, the respective contributions that sciences and the humanities can make to its epistemological and scientific foundation. We often hear and read that the Anthropocene is a too complex subject to be accounted for by Earth sciences alone and that the humanities should be more involved in the discussion. These complaints, however, do not always come with constructive suggestions. More often than not, they end up widening the gap instead of bridging it. Most importantly, the term

[1] Julia Adeney Thomas is among the historians at the forefront of the attempt to create an agenda for multidisciplinary research, as testified to by her numerous publications and projects in collaboration with members of the International Anthropocene Working Group (AWG). See her most recent edited volume *Altered Earth* (Thomas 2022). See also Thomas et al. (2020); Horn (2019).

'Anthropocene' is accused of hiding social inequalities and of reducing human diversity to the concept of an abstract *Anthropos*—an ahistorical entity that does not reflect the reality of the world's unequal distribution of wealth, prosperity, and responsibilities.

This alleged shortsightedness has pushed some to even refute the term 'Anthropocene' and the meaning that it entails. In *Against the Anthropocene*, T.J Demos argues that the term should be challenged in its legitimacy and replaced with alternative proposals (Demos 2017). In his view, the Anthropocene rests on the same hegemonic narrative that forged global capitalism, bracketing questions of power, class, race, gender and anthropocentrism. In this respect, Demos feels closer to the term "Capitalocene" endorsed by Jason Moore, which highlights the world system-ecology that we inhabit in a much more meaningful way. Moore's arguments, however, are somewhat ambivalent. On the one hand, he recognizes that the Anthropocene is a powerful concept and a worthy starting point to raise questions that are fundamental to our times. He believes that Earth-System scientists are effectively showing and communicating the rapidly changing conditions of life on our planet and the fact that we are currently living in a new geological epoch, different from the Holocene. On the other hand, Moore believes that the concept should be rejected based on its fundamentally bourgeois character (Moore 2016, especially 1-13): it does not explain the causes behind the environmental crisis we are facing, and this is enough for Moore to dismiss the work of scientists as messy, wrong and even fanciful (ibid., 29).

According to Ian Angus, Moore chooses to disregard, ignore and discredit any scientific effort to achieve a global picture of the human disruption of Earth-System parameters and blames the term 'Anthropocene' as an expression of a neo-liberal attitude (Angus 2016a; see also Angus 2016b).[1] Earth scientists are accused of fostering a 'Cartesian dualism' in which humanity is understood as separated from the Earth System. Angus sees it as a factually wrong view that overlooks the sheer amount of work and data available in scientist's reports about how the Earth System changes in response to human pressure[2].

[1] According to Moore, the scientists who have identified unprecedented and dangerous disruptions of the Earth system are asking the wrong questions and studying the wrong topics.

[2] As one can learn from the numerous reports published in the framework of the International Geosphere-Biosphere Program (IGBP), developed in the late 1980s, the Anthropocene theory is intertwined with the emergence of Earth-System science, which notably studies the Earth's bio-

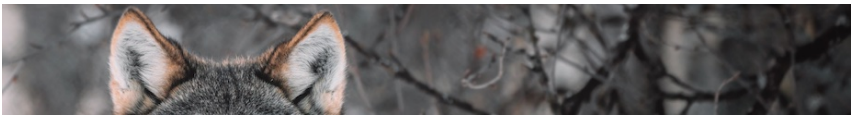
Demos takes similar stances to Moore, arguing that humans have unquestionably entered a new geological epoch. He recognizes that Earth-System scientists are diligently looking for the indisputable signals of the transition from the Holocene to the Anthropocene. He even admits that the sheer amount of scientific evidence provided by Earth-System scientists has outdated the idea of capitalism as the cradle of the human-made geological epoch. Science is irrefutable here. However, Demos (2017) also claims that 'Anthropocene' remains a problematic term that divides instead of uniting the scientific community.

Julia Adeney Thomas provides a remarkable and informative picture of these various defensive postures in her "Anything goes storytelling". Here 'Anything goes' refers to the array of imaginative terms and alternatives that have been proposed to *replace* the concept of 'Anthropocene'. These alternative terms incur the pitfall of maintaining a conservative tradition that separates human societies from the processes of the Earth System (Thomas 2022b, 54). In essence, some humanities scholars tend to adopt a confrontational or even boycotting attitude towards the work of geologists and Earth scientists, denouncing the inappropriateness of their methods and conclusions. In doing so they barricade themselves in the stronghold of political, cultural and anthropological criticism. Scientists are accused of offering an exceedingly abstract and homogeneous, if not erroneous, picture of the evolution of human society in the Anthropocene. Perhaps, Thomas continues, this criticism is a way to conceal the time needed to digest the complexity of the emerging Anthropocene science (ibid., 63).

One of the main targets of these harsh critics is usually the work of the International Anthropocene Working Group (AWG)—a component body of the Commission of Quaternary Stratigraphy (CQS)—which is often under accusa-

logical, chemical and physical processes and their interactions with human systems as a whole entity. In Angus's own words: "It seems, to be blunt, that Moore does not consider it important to familiarize himself with the subject he is criticizing. The few scientific papers he cites are mostly examples of what Jeremy Davies calls 'the simplest and most sketchily formed version of the concept, the first-draft Anthropocene' not the in-depth reports and analyses published by the IGBP, Future Earth, and the Anthropocene Working Group, the scientific organizations that have done the most to research the Anthropocene. Notably, none of his bibliographies includes the single most important overview of Anthropocene science, the IGBP's 2004 synthesis report *Global Change and the Earth System*. Failure to consult that essential volume is, all by itself, *prima facie* evidence of ignorance of the subject". Angus (2016), accessed on 27 August, 2022: `https://isreview.org/issue/103/knocking-down-straw-figures/`. See also Angus 2016.

tion for its attempt to pinpoint a specific moment in history in which the Earth's geology (and ecology) have irreversibly changed under the effects of human action. It is the work of the AWG that sparks the frivolity, distress, anger, and misconception of the 'Anything goes' stories detailed by Thomas (2022b, 63).



The AWG is tasked with defining and formalizing the Anthropocene by researching the appearance and presence of clear signals of the influence of humans on physical, chemical, and biological processes at the planetary scale. Anthropocene researchers thus search for noticeable evidence, or markers, including novel materials such as microplastics and alloys, black carbon from industrial combustion processes, biotic signals such as invasive species, disruptions in the carbon and nitrogen cycles and, most importantly for the purposes of dating strata, radiogenic substances resulting from atmospheric weapon testing. At the moment, the AWG has picked radiogenic fallout as the most promising 'golden spike' of the Anthropocene.

Despite the wide scope of the investigations of the AWG, its genuine interdisciplinary effort and the involvement of various actors (as evidenced by research and reports that go in the direction of integrating the human impact on Earth-System processes into the assessment of geo-stratigraphic markers),[1] humanities scholars find substantial limitations to its working methods, which consider a strict geo-stratigraphic mapping as the only plausible method to formally establish the beginning of the Anthropocene. A proposal must indeed fulfill three main criteria, decided in the framework of the International Commission on Stratigraphy: a synchronous base (a marker should be present at the same time everywhere around the globe); a specified position in the sedimentary record that defines this synchronous base (a Global Boundary Stratotype

[1] Will Steffen et al. 2106 show how stratigraphy and Earth-System science have built a multidisciplinary approach to the evolution of Earth, including the advent of the Anthropocene. See also Thomas 2022a.

Section and Point (GSSP) known as the 'golden spike'); and a specified rank in the stratigraphic hierarchy (stage, epoch, period, era).

On the one hand, the exact beginning of the Anthropocene is indeed a specifically geological question, related to the criteria and standards used by this discipline. On the other, humanities scholars deplore that the search for the 'golden spike' does not take into consideration the socio-cultural dynamics embedded in our economic system and does not tell us much about the driving forces underlying the current global crisis or the global distribution of material markers, such as plutonium or toxic particles.

One of the main grievances was perhaps expressed by Kathryn Yusoff in her *A Billion Black Anthropocene or None,* in which the work of AWG is almost denigrated for failing to contemplate any ethical crisis, siding with liberal and 'whiteness' discourses:

> The origin stories of the Anthropocene construct a monolithic, post-racial 'we' and singular temporality of being instead of differentiating geologic life along this praxis. Humanism is deployed as a method of erasure that obfuscates climate racism and social injustice in access to geography through differentiated histories of responsibilities and reward in geologic life. (Yusoff 2018, 57)

This accusation of 'monolithism', which does not take into account the different and varied domains addressed by the AWG, regards the search for a 'golden spike' as a sensationalist product, impervious to any criticism, and as the culmination of geological determinism. This condemnation led Yusoff and others to believe that it is not only impossible but even disrespectful to establish a beginning for the Anthropocene: we should instead opt for a multiplicity of episodes and events in history to explain the origins of our current global environmental crisis. According to Kim Fortun,

> instead of pursuing consensus terms, rotating around apical points, it may be best to pursue multiplicity—multiple start dates, multiple ways of analyzing and naming, multiple (variegated) effects, multiple resulting responsibilities: infrastructuring capacity to see things in different combinations, as with the turn of a kaleidoscope. (Fortun 2021)

This attempt to problematize the Anthropocene by rejecting a starting date supports the view of humanities scholars about the critical issues and constraints inherent in the scientific methodology of geologists and Earth scientists from

an epistemological point of view, but has not proven fruitful in strengthening a collaboration that might benefit both communities. Rather, it seems to be a way to slow down collaboration and hinder the recognition of the Anthropocene as a real phenomenon. Instead of starting a dialogue from shared points and then broadening the framework to enrich our understanding of the widely differentiated historical processes collectively responsible for anthropogenic planetary change, there is a tendency to reject *a priori* the mission of locating the synchronic markers that would orient the selection of the above-mentioned GSSP. As noted by Thomas and Renn (2022, 2020) the search for a GSSP would not hamper simultaneous and subsequent efforts to address the Anthropocene from a wider perspective that would call into question the history of human culture, the benchmarks of the evolution of our economic system and its scientific and technological machinery (and weaponry). Therefore, in some respects, obstructing and misinterpreting the work of AWG seems as dangerous as denying climate change or the environmental crisis. In order to be understood, the current situation needs a much more substantial effort from a truly interdisciplinary community. So far, it seems that interdisciplinary attempts have rather been the occasion to revive old frictions, deriving from the science and humanities' tradition of compartmentalizing knowledge. The Anthropocene calls for a novel framework to productively address a planetary system in which humans are the most disrupting component.

In this respect, the concept of 'Geoanthropology' can successfully express the urgency of developing and enriching our understanding of human cultural evolution in light of the Anthropocene and the tools needed for an interdisciplinary dialogue[1].

The next pages will briefly introduce geoanthropology as a theoretical framework that can help us historicize the Anthropocene, its markers and significance from a point of view that aims at re-integrating rather than dividing the different disciplinary perspectives involved in Anthropocene research. I will provide an example of geoanthropological research by introducing the project *Anthropogenic Markers: Context and Narratives*, including an experiment of in-

[1] Geoanthropology was developed by historian of science Jürgen Renn (Director of the Dept. 1 of the Max Planck Institute for the History of Science in Berlin and Founding Director of the Max Planck Institute of Geoanthropology in Jena) and his team. See Renn and Rosol 2020.

terdisciplinary collaboration with the AWG. I will then review a few historical reflections that conceptualize the Earth as shaped by human beings and where the *anthroposphere* is not treated as an abstract entity: on the contrary, it is fully rooted in a material dimension that problematizes Chakrabarty's distinction between the "global" as a human-centric category and the "planetary" as a scientific construction that removes the human and decenters its responsibility (Chakrabarty 2021). It will also challenge the concept of "Anthropogenesis" as an undifferentiated social stratification suggesting the production of a mythic Anthropos as a geological world maker and destroyer, as Yusoff argued in one of her articles.

2. Experimenting with Geoanthropology: Anthropogenic Markers

Geoanthropology is a new domain of research that addresses the relations between the *geosphere* and *anthroposphere* and that studies the various mechanisms, dynamics, and pathways that have moved us into the Anthropocene. Geoanthropology was conceived to address the challenges of the Anthropocene as the result of the accumulated impact of an industrialized humanity. It is therefore concerned with studying the *co-evolution* of natural, sociotechnical, and symbolic environments in an integrated and systemic manner. Former categories that treated Earth, life, human culture, science and technology as distinct are overcome in the Anthropocene, which presupposes the interdependency of these elements. Geoanthropology takes seriously the intricate interrelation of biophysical and ecological processes, the diverse social, political and economic processes, as well as human cultures and histories, including mentalities, beliefs and traditions. In other words, it presents itself as an all-encompassing

science that shifts between the analysis of specifically scientific and technological micro-spheres and the planetary macro-sphere.

Renn, who pioneered this research effort, describes geoanthropology as a mode of research that overcomes traditional borderlines between natural sciences, social sciences, and the humanities:

> One might call this domain of research—human-Earth interactions within an Earth System perspective" (Renn 2020, 375). Geoanthropology "should look at how key systems such as the energy system, the global flow of materials and information, the system of agriculture and land use, industrial chemistry, and the global transport system interact with one another and with the natural spheres—such as the terrestrial and marine ecosystems, geobiochemical cycles, hydrological cycles, and energy storage and transfer cycles across time and space—and it should investigate the role of knowledge in linking all of these processes. (ibid.)

Moreover, Renn stresses that geoanthropology cannot transcend the importance of modelling and integrated assessments. However, it should also "explore on a more fundamental level the environmental, social, economic, political, and epistemic dynamics of the interactions between human actors and the Earth System from historical, evolutionary, and systemic perspectives" (ibid., 376).

The main questions of geoanthropology include: what are the major transitions of Human-Earth Systems and how can they be accounted for? What are the processes that allow such major transformations to emerge? How can we redirect humanitarian values in such a way as to divert the Human-Earth System from a hothouse pathway and restore a 'safe operating space for humanity'?[1] According to Renn, investigating these questions requires a novel, integrated approach that brings together three dimensions in the study of Human-Earth Systems: the resource dimension (labor, energy, materials); the regulatory

[1] See Rockström, Steffen, Noone et al. (2009), "A safe operating space for humanity". By "safe operating space for humanity", the authors mean a space that could restore the balance between the Earth system and human development. The article identifies nine "planetary boundaries" (climate change; biogeochemical flows such as carbon, nitrogen and phosphorus cycles; chemical pollution; freshwater use; land-system changes; biodiversity loss; ocean acidification; stratospheric ozone depletion; and atmospheric aerosol loading). If exceeded, the thresholds of these planetary subsystems might affect the Earth's processes, with deleterious consequences for humanity and leading to irreversible environmental change. These boundaries therefore define the safe operating space for humanity. See also Will Steffen et al. (2018).

dimension (economy, politics, law, knowledge, belief systems, automatization, artificial intelligence); and the ecological and evolutionary dimension (biodiversity, ecological challenges, sociotechnical and symbolic environments).

The chronological configuration of geoanthropology encompasses historical and recent timescales as well as future trajectories and contemporary challenges. As for its spatial configuration, it cuts across the micro- meso- and macro-scales, namely the Earth and its sub-systems (including human-scale intervention) and the molecular dimension. This multi-faceted scale of description weaves together a variety of disciplinary approaches, such as complexity and Earth System Science, biosphere studies, political ecology, Anthropocene research, history of science, technologies, and economies, knowledge systems, environmental humanities, human geography, cultural studies, and anthropology. Their interconnection allows us to explore broad topics and specific case studies whose complexity could not be tackled through a single perspective. These would include, for instance, planetary urbanization and the technosphere (the sphere of technological objects and infrastructure covering the planet and altering its metabolic conditions), the agri-food system and the food web, planetary health, energy systems and transitions, information systems, digitalization, etc. What emerges from this articulated and at the same time synoptic picture is the groundwork for a basic science that studies humanity as an agent of the Anthropocene, thus enabling the emergence of a new category of Anthropocene scholars.

Geoanthropology has inspired a number of initiatives where history and epistemology are seen as the backbone of the Anthropocene. I would like to focus on the project conceived and designed by Christoph Rosol and myself, *Anthropogenic Markers,*[1] which led to a fruitful experiment in interdisciplinarity among Anthropocene scholars from the geo-sciences and the humanities. The project was organized around a dialogue between different AWG groups, tasked with researching specific categories of markers and sediments, and hu-

[1] The *Anthropogenic Markers* project directly contributes to the ongoing collaboration between the Max Planck Institute for the History of Science (MPIWG) and the AWG, the Haus der Kulturen der Welt (HKW) (a forum for contemporary art and critical debates with a privileged focus on non-Western origins), and the MPIWG. Together these institutes coordinate, fund, and contextualize the extensive endeavor of finding and defining the Anthropocene GSSP. For an overview of the entire project, see Rosol and Rispoli 2022.

manities scholars of various backgrounds. Researchers and artists of different origins and practices were thus offered valuable opportunities to learn from the work of the AWG, shaping a collective understanding of the Anthropocene in its geological, historical and cultural specificity. In addition to the unprecedented occasion to discuss and provide an historical account of the diverse cultural, intellectual, epistemic, social, economic, and political drivers that led to the production, distribution, and accumulation of the markers that signal the emergence of the Anthropocene as a new geological epoch, the experiment was specifically directed towards a synergy of perspectives in three main areas of knowledge: geo- and atmospheric sciences; history and epistemology of science and technology, including the discussion of the planetary crisis, of the risks and the future of humanity; and the socio-economic sphere, including the impact of a thermonuclear war, livestock industry, industrial agriculture and fertility regimes, human health and wellbeing. The exchanges among this diversified group of scholars led to the shared production of knowledge about geological analysis, interlaced with human agency in its diverse political, contextual and social aspects. It generated a sort of feedback loop where both communities learned about each other's methods and research on the Anthropocene and its markers and were able to discuss criticalities and limitations, as well as scientific and epistemological issues.[1]

The above-mentioned tendency to minimize the work of the AWG for its strict stratigraphic approach was deliberatively addressed, discussed and confronted constructively on this occasion. Indeed, since the interdisciplinary exchange stemmed from the main anthropogenic markers investigated by the AWG, the project aimed to expand on the narratives, causes and contextualization of these markers from multiple socio-historical and cultural perspectives. In a sense, what emerged from these debates was a kind of historical and political epistemology of the anthropogenic markers under investigation.

The special publication resulting from the project—*Anthropogenic Markers:*

[1] Groups of AWG members were invited to disseminate their research and fieldwork about specific types of markers and environmental archives. These essays were made available to the other participants in order to help them become familiar with the work of the group and with the selected markers. The essays and critical remarks of Humanities scholars, presented at a conference, responded to some extent to the output of AWG scientists. During the same conference, these contributions generated a lively debate and received in turn feedback from the AWG.

Stratigraphy and Context—reflects this overall effort. The contributions from various fields, collected into seven thematic dossiers, reflect on selected material markers of human impact on earthly strata. Taken together, they form a unique interdisciplinary conversation across positions and perspectives.[1] Each dossier opens with a technical and stratigraphic description of markers by the AWG, complemented or accompanied with a list of textual or visual contributions that offer different socio-cultural contextualizations of Anthropocene markers.

These markers are clustered based on their characteristics and on the realm to which they belong. The first category, named *Anthrobiogeochemical cycles*, refers to the anthropogenic impact on biogeochemical cycles such as the impact of carbon cycle on global warming, ice melting, sea level rise, etc. Another consequence is ocean acidification due to pollution. Changes in nitrogen and phosphorus cycles date back to the age of guano, the phosphate-rich natural fertilizer derived from the excrement of certain bird species that was the most effective way of fixing nitrogen in the 19th century (Cushman 2013). In some cases, humans have even tried to redesign planetary biogeochemistry.[2]

A second dossier is focused on *Biotic change*, referring to the markers that signal changes in the configuration of the biosphere, such as the extinction of animal species and deforestation, both causing a rearrangement of ecological and biological dynamics. The overexploitation of marine and terrestrial environments, and especially the destruction of habitats due to intensive farming, has accelerated the loss of biodiversity and has contributed to the introduction of invasive species. Plants or animals accidentally or deliberately introduced into a new and different environment create ecological problems that have socio-economic and repercussions also on human health. The story of the Pacific oyster is particularly relevant: after becoming an important part of the local economy, its farming generated a complex division and exploitation of labor and manpower and the consolidation of a capitalist system. Social inequalities

[1] See the "Editorial Introduction" in Rosol and Rispoli (2022).

[2] One recent example was the menace of a thermonuclear war between the Soviet Union and the United States, an event that could cool down the Earth's temperature to such an extent that it would alter the atmospheric processes and biological components of the planet. According to the AWG, the career of the Nuclear Winter is a way to contextualize the history of plutonium as one of the most suitable radioisotopes to mark the start of the Anthropocene. This marker will be identifiable in sediments and ice for the next 100,000 years. See Rispoli (2022).

became more evident, due to the many slaves working in these oyster cultures.[1] Another example is the history of the Wardian case i.e., Dr. Ward's box, This kind of small portable greenhouse or *terrarium* became widespread in the Victorian era in the 19th century and introduced a number of invasive species (insects, etc.) that devasted the territory and contributed to shaping European colonization and the global trade (Keogh 2022).

A third dossier is concerned with *Combustion* products as markers of the Anthropocene. These can include material sediments such as spheroidal carbonaceous particles derived from the combustion of coal and oil and accumulated in the Earth's strata since the Industrial Revolution (black carbon, soot, etc.).

These chemical stratigraphic signatures epitomize a history centered on heat and energy and in which social and climate changes are intertwined. Moreover, they make visible what we cannot see when we breathe, exposing the materiality of air pollution. The contributions featured in the dossier range from the fundamental role of fire control in human history and cultural evolution—and its new significance as a powerful tool of geo-technological agency after the increase of fossil fuel burning—to the effects of carbon black from the smog-filled streets of St. Louis, Missouri, during the 'Black Tuesday' of 1939, to the burning tropical forests of Indonesian provinces in 2019 and the documented practices of 'mining whales'. Whale oil and spermaceti, the energy sources derived from whale tissues, were used primarily for lighting but became a powerful tool of industrialization and colonization (Clark 2022; Puri 2022; Sobecka et al. 2022). A fourth dossier titled *Critical Environments* discusses broader environmental and socio-ecological issues through a variety of case studies. An example is the hydrogeological and urban history of Venice, where anthropogenic interventions have deeply affected the lagoon and its surroundings, including the coast and floodplain (Omodeo and Trevisani 2022; see also their paper in this issue).

The fifth dossier, *Novel Materials and Technofossils*, concerns the artifacts produced by our society that may become part of the geology of the Earth in the future, as was the case with the stone tools and lithic instruments of our dis-

[1] The Pacific oysters were imported to the San Francisco area in the 17th century. Today, this species poses a threat not only to the local economy, but more importantly to the whole ecosystem. These biological organisms are also used as markers, as they capture every trace of elements such as mercury, cadmium, lead, ash, plastic, plutonium, and thus functioning as a natural archive of human impact at different levels and concentrations. See Barnosky et al. (2022).

tant ancestors. When these artefacts become fossilised underground, mining and drilling can cause them to penetrate and impact deeper layers of the Earth's crust. A plastic bag or a ballpoint pen can be trapped in the rock layers for a long time and impact the environment not only in the present but also and especially in the future. Archaeology then becomes the study of how our civilizations have shaped not only the past but also the future of our territories. Archaeologist Matt Edgeworth redefines the biosphere as an *archeosphere*, precisely to emphasize the set of externally visible but also Earth-penetrating infrastructures that support our urban systems and activities (Edgeworth 2014). Interestingly, Sverker Sörlin mentions that 'geoanthropology' used to be a term (with limited circulation) that referred to the interface of geological and archaeological sciences (Sörlin 2022).

A sixth category of markers includes the byproducts of the nuclear age, that is the radiogenic material from atmospheric nuclear tests that will persist in sedimentary records for the next few hundred thousand years—first in the form of plutonium, then decomposing into uranium and finally into lead. These markers fall under the umbrella category of *Nuclear Anthropocene*. The potentially most widespread and globally synchronous anthropogenic signal is the fallout from nuclear weapon testing that began in 1952 and peaked in 1961–1962, leaving a clear global signature concentrated in the Northern Hemisphere. The mid-20th century is therefore the historical period that encapsulates most of the global changes that affect the Earth System and socio-economic trends: for example, the abuse of artificial fertilizers, the rise of pollutants, oil and gas prospection and exploitation, and biodiversity loss. The Great Acceleration (GA) graphs capture the interconnection of these complex phenomena, showing how, during the 1950s, the curves of numerous parameters pertaining to the Earth System and to socio-economic trends shifted from linear to exponential growth[1]. Therefore, the majority of members of the AWG agree that the mid-20th-century GA was a major turning point in history, signaling a global shift in the condition and functioning of the Earth System.

[1] The concept of the 'Great Acceleration' was already used, under a different name, long before the Anthropocene discourse. Christian Pfister, a Swiss economist and environmental historian, had already indicated the middle of the last century as a major *turning point*, calling it the ''1950s syndrome''. See Pfister 2010; Steffen et al. 2005; Steffen et al. 2015; McNeill and Engelke 2016.

Most importantly, the different analyses of the GA show a substantial evolution of its interpretation over the last years. For example, Christoph Görg et al. (2019) discuss how the interpretation and the data collection that led to this iconic graph, which plots together Earth System and socio-economic trends, are being expanded towards a more political interpretation of the concept and message of the GA. Questioning the homogeneity of the initial GA graph in its initial formulation, which failed to identify any differences and regional variations in social and economic development patterns, Görg et al. propose to reinterpret the phenomenon as substantially uneven. By integrating social ecology and political economy in their historical approach to capitalist development, seen as a non-linear phenomenon, they highlight social inequalities and justice issues in relation to the rate of resource exploitation and economic growth in different (developed and developing) countries. As the authors write:

> To better understand the different patterns of resource flows, for example, within the broad variety of industrialized countries and between them and resource exporting countries in the Global South, we need an approach that helps to explain the drivers involved and how patterns of resource and material use as well as energy develop over time. Capitalist development over the last 150 years is characterized by very different economic growth models with varying dependencies on certain resources (e.g., from coal to oil and gas, but also regarding new IT technologies), modified by certain political (e.g., the welfare state) and cultural patterns (e.g., the role of certain consumption patterns). (Görg et al. 2019, 44)

Although Görg et al. take into consideration the fact that the power relations and the inequal access to resources between the global north and global south is rooted in the rise of fossil capitalism (as Andreas Malm [2016] would call it), the authors do not recommend renaming the Anthropocene "Capitalocene", as suggested by Moore: "First, the thesis of the Capitalocene neglects the major shifts in the 20th century and the biophysical challenges involved. Second, it ignores the institutional, political and cultural institutions responsible for the First and the Second Great Acceleration and thus conceals the entry point for social-ecological transformations" (Görg et al. 2020, 54).

The recent focus on the GA shows that the Anthropocene debate is no longer of interest only to geologists and geo-stratigraphers. In this sense, it is important to stress that AWG also supports a geoanthropological approach, opting for

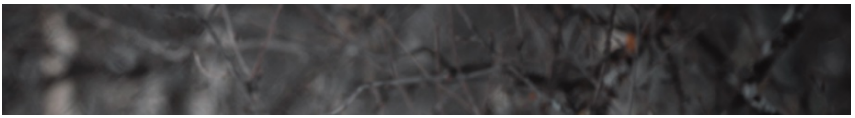
a wider understanding of the Anthropocene that goes beyond detecting human influence on stratigraphy, and ''reflects a substantial change in the Earth System'' (Zalasiewicz et al. 2015, 197) – a change that has of course different origins and is associated to different phenomena. This openness and hybridization of the methods, discourses, and applications of Anthropocene research is the focus of the seventh and last dossier of *Anthropogenic Markers*, titled *Strata, Symptoms, Signals*. The dossier reflects on cultural, social and political markers as much as physical and material ones. It carries out a meta-analysis of how markers can be narrated through a myriad of stories and events that complement different aspects and traditions of the evolution of our societies. As claimed by Renn and Nathaniel La-Celle Peterson, it is a matter of learning to understand what counts as a "sign". In other words, we need a new global semiotics and a sphere of significance to reckon with the current situation and learn to decipher the signs of the interface between natural archives and human societies (La Celle-Peterson and Renn 2022).

As observed by Peter Haff, the earth scientist and member of the AWG who revived the technosphere, "narratives whose starting or ending points connected to specific types of GSSP-candidate deposits could help provide the threads of a fabric illustrating a broad view of the Anthropocene. As contributors to the same fabric, our stories, discoveries and explanations would each represent a step toward creating a more unified view of a new epoch in Earth history. In a biological, geological metaphor I imagine a complex ecology rooted in Anthropocene sediments. The point would be to emphasize that the Anthropocene is not just science and technology and impersonal forces, that it's not just humans and human relations, but it's the whole interconnected thing".[1]

Recognizing the Anthropocene and the science behind it is the first step towards a new political analysis, capable of generating a common understanding and an increase in multidisciplinarity (Thomas 2022b, 63). Therefore, detractors of Anthropocene-related terminology and scientific work (the search for a "golden spike" and the contribution of Earth-System scientists) are working against these objectives and fail to recognize the current planetary emergency,

[1] Personal communication with the author on November 3, 2020 in the framework of the *Anthropogenic Markers* project's introduction and further planning. On the interpretation of Haff's technosphere, see Omodeo in this Issue.

silencing a potentially valuable contribution to the production of a new language and semiotics.



3. Historicizing geoanthropology

Although geoanthropology is a young discipline, the concept has been used by several renowned scholars. Sörlin, a historian of science, refers to geoanthropology as a key concept alongside the "planetary boundaries" proposed by Röckstrom et al. According to Sörlin, the evolving science of geoanthropology would enable a "synchronization of temporalities", that is "the multiple coexisting times of the Earth System that are becoming a matter of acute concern in the Anthropocene overcomes the conventional history time-scales in use in environmental history" (Sörlin 2022, 5). This kind of generative work would allow environmental historians to move away from their conservative traditions, where the concepts of climate change or environmental crisis are preferred over that of Anthropocene. Interestingly, Sörlin mentions a history of the synchronization work conducted by Helge, Herder, and other philosophers of time in the early phases of industrial modernity, which paved the way for the global world of a common humanity, chiefly an accomplishment of humanist anthropology (Sörlin 2022, 43).

The task of retracing the historical attempts to describe the Earth as dominated by human agency was already initiated by atmospheric chemist Paul Crutzen and biologist Eugene Stoermer. In the *Global Change Newsletter*, where they submitted to a scientific audience the word 'Anthropocene' as preferable to 'Holocene', they refer to a list of prominent pioneers of the concept[1]. American

[1] Crutzen was awarded the Nobel Prize in 1995 for his research on the depletion of the ozone layer due to carbon dioxide emissions. He proposed the term "Anthropocene" in 2000, together with Eugene Stoermer, introducing it officially in the newsletter n. 41 of the International Geosphere-Biosphere Program. See Crutzen and Stoermer 2000.

diplomat George Perkins Marsh, for example, wrote that during the Holocene human activities gradually grew into a significant geological, morphological force. Already in 1864, he published a book titled *Man and Nature*, later reprinted under the title *The Earth as Modified by Human Action* (Marsh 1874). Marsh retraces the physical decay brought about by humans on lands, waters, and sands since the Roman empire. He shows how reckless human operations have affected the organic and inorganic worlds, exterminating numerous forms of animal and plant life. Thus, Marsh recognizes to some extent the role of human activities in the extinction and loss of biodiversity. He also mentions the phenomenon of species translocation caused by human intervention, although he does not acknowledge the associated risks. According to Marsh, the transforming power of humans is more vigorously exerted on superficial geography and especially on animal and plant life as well as forests, due to industrial development and to the great projects of physical change now referred to as geoengineering (1874, Preface, VI). Although his text remains a milestone in raising awareness about the dangers of deforestation in the United States, about land degradation and the importance of conservation, his effort remains circumscribed to what we would call environmental history. Marsh fails to take the ontological leap from the biosphere as we know it (although the term was not yet popular at the time) to another, *qualitatively* different stage.

Another author mentioned by Crutzen, the 19th-century Italian geologist Antonio Stoppani, also stresses the impact of humans on the geology of the Earth. In his *Corso di Geologia* (Geology course), he describes the current period as *Antropozoico* (Anthropozoic). However, no human artifacts testify to this transition (Stoppani 1873, 327). Interestingly, Stoppani believes that humans have not been around long enough to leave a trace in the Earth's fossil record. There are no sedimented signatures or markers of this transition yet. Indeed, Stoppani refers to his time not as a geological epoch but as a historical one, presumably because humans are clearly recognized as its protagonists. Nevertheless, he compares the human transformation of the Earth to a sort of volcanic activity, to an earthquake shaking the Earth's crust.

Among other pioneers mentioned by Crutzen in his overview of the conceptual history of the Anthropocene, Vladimir I. Vernadsky is certainly the one who gave substantial depth to these preliminary analyses. The life and work of this notable scientist, born in 1863 in Petrograd, member of the Russian

Academy of Sciences and founder and first President of the Ukrainian Academy of Sciences, are well documented in the literature—especially his formulation of "biogeochemistry" as a new approach that studies living and inert matter as an entangled system, and of the concept of the "biosphere-geosphere"[1]. Let me focus on his interpretation of the *noosphere* (from the Ancient Greek word νοῦς, intellect) and put it in relation to the above-mentioned concept of 'technosphere' and the epistemic evolution proposed by Renn.

Vernadsky seeks to historicize the role of the *anthropos* in the geological transformation of the Earth without treating humanity as an undifferentiated and abstract entity. His analysis is rooted into the material dimension of human historical, cultural, and scientific development, and deeply connected to its geographical context. Moreover, he seeks to rematerialize science and technology instead of sublimating and detaching them from human responsibility. According to Vernadsky, humans have been modifying their surroundings since their appearance. However, the urgency for humans to regain planetary agency in order to reverse the march of progress that has catheterized Western civilization was never felt as strongly as in the 20th century. Previous attempts were not in the position to grasp the planetary significance of these processes.

Back in the late 16th century, Francis Bacon already advanced the idea of man's supremacy over nature as the goal of the new science, and Georges-Louis Leclerc De Buffon contextualised it in the history of the planet not only as an idea but as an observable natural phenomenon[2]. The American geologist Joseph Le Conte described the phenomenon of the "psychozoic era"—the evolution of all living organisms in a specific direction, and geologist James Dwight Dana, a contemporary of Darwin, referred to the same process with the term 'cephalization'. In Russia, geologist Alexey P. Pavlov coined the interesting term 'Anthropogenic era' at the turn of the 20th century. Vernadsky reports that Pavlov describes humankind as an ever-growing geological force that formed gradually

[1] On Vernadsky's life and work, see Bailes 1990; Grinevald and Rispoli 2018; Grinevald 1998; Rispoli 2014; Rispoli 2023.

[2] "Buffon proceeded from the hypothetical reconstructions of the past of our planet tied up with the philosophical intuition and theory and not with the precisely observed facts. But he sought for such facts. His ideas covered the area of the philosophical and political thought. There can be no doubt that they had influenced the course of the scientific thought" (Vernadsky 1997, 41). See also Omodeo 2021.

and imperceptibly. His specific connotation of 'anthropogenic' is deeply connected to a material and symbolic context: "The main influence of the human thought as a geological factor is revealed in its scientific manifestation which is a decisive factor in organizing the technological work of the humanity, altering the biosphere" (ibid., 44). In this context, labour created the conditions for humans to exert a form of biogeochemical power that, with time, has come to be ideologically recognized. Certainly, this power was exerted unintentionally and unconsciously. Indeed, the notion of unity of humankind does not exclude struggles, conflicts, mutual exterminations, brutal invasions, etc.

However, as a rule, the urge to master the surrounding nature characterizes all human history. The scientific culture of the New World was no less advanced in many aspects than that of Western Europeans: "The American aboriginal civilization collapsed because the Indians did not know military technology and fire-arms which became usual in the everyday life of West- Europeans several decades before the discovery of America" (ibid., 51).

Yusoff and Povinelli reject the adjective "anthropogenic" as exceedingly abstract, univocal and therefore conducive to a depoliticized view of the Anthropocene (Povinelli 2016; Yusoff 2018). By doing so they overlook the epistemological and material nuances (values, cultures, ideas and visions) that Pavlov and others ascribe to it. The "Anthropogene" is actually an alternative to the Western scientific traditions that Yusoff and Povinelli are trying to circumscribe and demonize. In this sense, their crusade against the 'Anthropos' turns out to be even more partial while pretending to describe the neoliberal ascent of the term 'Anthropocene' (and annexed suffixes) and its global rhetoric in the current science-policy nexus and Earth-System governmentality.

Although previous attempts to highlight the transformative power of our species are grounded in empirical observations and generalizations, Vernadsky claims that it was the Second World War that triggered an unprecedented climax, with deep repercussions on the economy, statehood, and the rise of nationalisms and power. All these phenomena should be considered as part of a geological process and not merely as historical events with local consequences (Vernadsky 1945, 5). Before the mid 20th century, the transformation of the biosphere caused by humankind could be considered of *historical proportions* (in line with Stoppani's view) and not yet of *geological* ones (ibid., 8). Vernadsky believed that in the mid-20th century, humankind became "a single totality in the

life of the Earth" (ibid.). This does not mean that there are no differences within humankind: however, according to Vernadsky, although the life of humanity is highly heterogeneous, in the 20th century it became almost indivisible because "an event having taken place in any remote part of any continent or ocean, is reflected and has major and minor consequences in many other places over the surface of the Earth" (Vernadsky 1997, 39). In the historical context, that is according to the history of different progenies and civilizations, this unity does not come without consequences; however, this very same *wholeness* now represents, according to Vernadsky, a starting point to imagine new ways of recoupling with the biosphere (ibid.).

Along similar lines, geographer and environmental historian Simon Dalby examines in a recent book the transnationality of the climate and environmental crisis. He addresses the geopolitics of the Anthropocene as a phenomenon that crosses borders and therefore requires a new way of understanding the boundaries, nations, and people implicated in this matrix. Most security policies, for example, continue to be built on obsolete notions from an era when geopolitical threats stemmed primarily from rivalries among states with fixed borders. Instead, the Anthropocene shows the urgency of finding a new unity to shape a sustainable world, fight environmental exploitation and injustice and find alternatives to fossil fuels (Dalby 2020).

According to Vernadsky, since the 20th century we have been living in a system called the *noosphere*, in which humans have become aware of their geological role on Earth. At the same time, humans have acknowledged that their power can be destructive, that human intellectual power must be used more wisely and that the march of progress that has characterized Western civilization since early modern times must be abandoned. Vernadsky understood the severe consequences of the exploitation and manipulation of nature and was aware that in the 20th century humans have scaled up their influence on Earth to an unprecedent level. For example, they have created new minerals: metals like aluminum and titanium are being produced in huge quantities. Today, these observations sound particularly alarming and topical: mineralogists are now able to quantify the sheer number of new minerals that have been produced in the last century. Zalasiewicz has recently observed that the International Mineralogical Association has quite paradoxically excluded human-made minerals from its classification because including such an overwhelming amount

of recently created compounds would make the science of mineralogy utterly unpractical (Zalasiewicz 2022, 31).

Vernadsky proceeds by listing all the other markers that reveal the power of humanity as a geological force; for example, humans have created new chemical bonds and compounds; introduced new species into territories to which they were not endemic; created novel organisms (*neobiota*); domesticated animals; they have physically and chemically changed the air, lands and waters; and reconfigured shores, created urbanscapes, etc. In the previous paragraph, we have briefly outlined all the domains and the natural archives of human signatures (anthropogenic markers) registered and identified by the AWG. Vernadsky mentions many of them in his conceptualization of the transition from the biosphere to the *noosphere* and reflects on the importance of retuning democratic ideals with geological process (Vernadsky 1945, 10). In this respect, he ascribes a central role to science and technology as a byproduct of human knowledge. The shift from biosphere to noosphere is substantially caused by the scientific and technological advances of a civilized humankind. In this respect, Vernadsky's noosphere can be compared to Haff's technosphere. These two notions share a few premises, although they strongly differ in their conclusions.

The term 'technosphere' is used by Haff to refer to the current state of the Earth System, controlled by global technologies that have gradually changed the metabolic processes of our planet. The technosphere includes large-scale energy and resource extraction systems, power generation and transmission systems, communications, transportation, financial and other networks, governments and bureaucracies, cities, factories, and farms, as well as all farm equipment such as computers, windows, and tractors (Haff 2014; see also Omodeo in this issue).

Similarly, Vernadsky wrote in the 1930s that in the 20th century our technological system has become so widespread as to drastically remodel the entire *envelope* of the Earth. "Telegraph, telephone, radio, aeroplanes, aerostats have covered the whole globe. The communications became simpler and faster. The degree of (human) organization rapidly improves, from year to year" (Vernadsky 1997, 39). In the 20th century mobility and transport became global phenomena and humans realized for the first time that they were inhabitants of the planet. The noosphere is characterized by an increase in demography; the transformation and globalization of communication and trade across the planet;

the industrial exploitation of new sources of energy, etc. These 20th-century phenomena are highly reminiscent of the notion of Great Acceleration. But an important difference between the technosphere and the noosphere consists in the fact that, in Haff's elaboration, the technosphere becomes a complex system that operates outside human control but imposes constraints on human behavior and collective decision-making. The widespread and complex organization of the planetary technological system makes it difficult to perform any kind of intervention. In particular, the technosphere emerges as a completely autonomous system (Renn 2020; see also Renn 2016; Donges et al. 2017; Ienna and Rispoli 2021). According to this interpretation, human societies have produced a planetary-scale technological system that now exists independently, imposing limits on human action and decision-making.

The perspective outlined by Haff delocalizes and reduces human responsibility, regardless of the changes that humanity has caused on Earth and of the deep alterations to the general functioning of the biosphere. Most importantly, by denying human collective agency, the concept of "technosphere" precludes any possibility of producing new policies. On the contrary, Vernadsky's noosphere cannot be autonomous from human society because its current state stems from human history, which is inseparable from human scientific knowledge. In other words, scientific knowledge reveals the history of a new and crucial geological factor in the biosphere—namely humanity. As Vernadsky points out, there is an inseparable connection between the creation of the noosphere and the growth of scientific thought, which is the necessary condition for its emergence.

The concept of 'noosphere' reminds us of today's pressing need to address, collect, and reflect upon historical attempts to conceptualize science and technology in relation to the material and cultural conditions of our society. Therefore, it allows us to investigate how cultural and scientific practices have shaped our understanding and perceptions of nature and natural resources in relation to social changes and economic progress (ibid.).[1]

[1] Interestingly, according to Vernadsky, scientific and technological progress goes hand in hand with the progress of human knowledge about the Earth and its sub-systems. For example, the mastery of new forms of energy—steam, electricity, atomic energy or radioactivity—facilitated the study of the biosphere as a thermodynamic system where solar energy is absorbed and then radiated as heat, while mining, boring and drilling when searching for coal, oil and ores made it possible to perceive the depth of the Earth's crust and the transformative geological capacity of human activities.

In this context, it is worth mentioning Renn's concept of "epistemic evolution"—a new stage of cultural evolution that becomes the dominant process of human history and in which science and technology become existential factors. Renn underlines that our evolution as a society

> has become crucially dependent on the global knowledge economy and, in particular, on the scientific, technological, social, political, and other kinds of knowledge it has generated and distributes. A particular role is played by that knowledge necessary for creating, maintaining, and further developing the large social and technological infrastructures on which global cultural evolution has become dependent. (Renn 2020, 324)

Therefore, as humans become aware of their power to shape the Earth and become a geological force, it is plausible that science should emerge as a dominant factor of our current situation—not as the necessary result of some initial conditions, but following a process that is also contingent, as in Darwin's theory of evolution (ibid.). As Renn points out, getting even closer to Vernadsky's noosphere, humanity has entered a new phase of cultural evolution (ibid.).

According to Renn, opposing the interpretation of the Earth System as a super-organism that functions autonomously from human agency requires two basic positions. First, it is fundamental to rematerialize scientific and technological production and ground them in the social fabric. Second, we must underline the fluid relationship between science and society as well as the reconstructive possibilities of an environmental niche in which humanity can address the problems caused by the technosphere and ultimately abandon the technologies that are moving the Human-Earth System away from a safe operating space (ibid.).

Similarly, Vernadsky's concept of 'noosphere' is as a new niche of cultural and epistemic evolution. He thought that the new conditions of contemporary humanity as a fundamental force in geological history have emerged through the development of those aspects of human knowledge that are tied to natural sciences, math, technology (Vernadsky 1997) etc., shaping a knowledge system

The invention of telegraph and radio enabled communication between faraway places, shortening distances and contributing to the sense of our globe's interconnectedness. All these and later processes are firmly grounded in human scientific and technological developments, and yet they have completely changed the biosphere, which has been heavily reconfigured and redefined both in its biological components as well as in the way it interacts with other spheres such as the atmosphere and lithosphere. See also Rispoli 2023.

that allows the noosphere to expand and in turn depends upon them. In this respect, the noosphere is characterized by the emergence of a new awareness in which the integration of cultural and geological agencies is consciously achieved in its epistemic and co-evolutionary character.

As Vernadsky writes,

> the philosophical representation of the world in its general outline and particularities creates the environment wherein scientific thought exists and develops. To a certain (not insignificant) degree, this thought itself is a condition of its environment, while the achievements of this thought may also change this environment. (Ibid., 42)

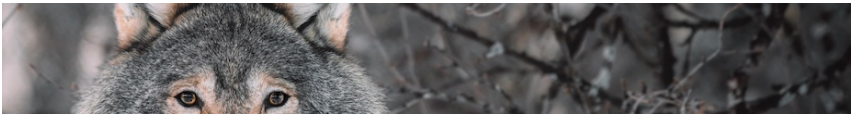
Moreover, according to Vernadsky the noosphere represents a qualitatively different level of epistemic evolution:

> Up to this time, the history of the mankind and its spiritual manifestations is studied as a self-sufficient phenomenon, freely and irregularly displayed over the Earth surface, in the environment that surrounds the Earth, as something strange to it. The social forces that manifest themselves through the history are thought of as something to a considerable degree free from the environment wherein the history of mankind involves. (ibid.)

On the contrary, in the 20th century the process of human co-evolution with the environment, aided by science, manifests itself with unprecedented clarity. Vernadsky believes that 20th-century science marks a clear distinction in terms of organization of knowledge—in the *rate* of scientific movements; in the *area* embraced by science and spreading across planet; in the *depth* of the influence of ideas about scientifically accessible reality; and finally, in the *strength* of the planetary change caused by science and in the prospects for the future. These changes are so massive that the impact of science and scientific actors on the biosphere can now be perceived on an unprecedented scale (ibid., 90). Indeed, "the course of the history of the scientific thought becomes for us a natural process of the history of biosphere" (ibid., 54).

To conclude, what are the characteristics that should distinguish the noosphere from previous periods when humans had not yet realized their planetary agency, i.e. their capacity to produce knowledge on a global scale and thereby affect the Earth System? Vernadsky's first and somewhat idealistic premise is

the unity and equality of all people, which explains his call for social and political justice. Biologically and geologically, this is expressed in the manifestation of humankind as a unity in relation to the rest of the planet's living population. The noosphere should be the first step to recognize the urgency to recompose a unity that has been completely disrupted by violent historical events. Even though humankind's technological force has the potential to irreversibly change the biosphere, this does not have to be the case. These forces must be stopped or reoriented toward safe operating thresholds in order to prevent the unintended consequences of human action from generating environmental processes that may lead societies to a full collapse. Thus, the noosphere appears to have the power to ignite a constructive impulse towards new forms of collective human action. If built on values of democracy and equality, it could prevent social and environmental catastrophes and end malnutrition, hunger, poverty and war. Understanding that we can bring about large-scale changes to the Earth System also invites us to reflect on these processes and even orient them. In this respect, formalizing the Anthropocene as a geological epoch can make a difference in redirecting human actions towards a safe operating space.



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