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Soft Power
Revista euro-americana de teoría
e historia de la política y del derecho

Vol. 10(1). Enero-Julio 2023
ISSN (online): 2539/2239 ISSN (print): 2389-8232
http://dx.doi.org/10.14718/SoftPower.2023.10.1.2

AFTER NATURE. THE IDEA OF HABITABILITY IN THE CONCEPTS OF GAIA, CRITICAL ZONE AND TERRESTRIAL IN BRUNO LATOUR'S POLITICAL ECOLOGY*

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DESPUÉS DE LA NATURALEZA. LA IDEA DE HABITABILIDAD EN LOS CONCEPTOS DE GAIA, ZONA CRÍTICA Y TERRESTRE EN LA ECOLOGÍA POLÍTICA DE BRUNO LATOUR

Abstract

In this paper I aim to show the relevance for social and political theory of some of the conceptual performances of Gaia and Critical Zone and the connections of these

* Reception date: 19th February 2023; acceptance date: 27th March 2023. The essay is the issue of a research carried out within the Dipartimento di Scienze Politiche e Sociali, Università degli Studi di Firenze.

performances with the concept of the Terrestrial. These three concepts play a key role in the 'political turn' that has characterised Bruno Latour's most recent theoretical work. The analysis is developed through the variations of the concept of habitability in Gaia, Critical Zone and Terrestrial, employed as a tool to grasp the semantic shifts from the scientific-naturalistic field to the political field generated by the changes that have taken place over the last twenty years in the way the different sciences of Life understand the logic of the habitability of planet Earth. Special attention in the analysis is given to the implications, for social and political theory, that the changes detected with Gaia and Zona Critica produce on the ideas of freedom and necessity once they have emerged from the modern nature/humanity dichotomy and on the logic of the conflicts that open up in the horizon of the Earth.

Keywords

Latour, Gaia, Critical Zone, Terrestrial, Habitability, Political Ecology, Ecological Class, Actor-Network Theory, New Climate Regime.

Resumen

En este artículo pretendo mostrar la relevancia para la teoría social y política de algunas de las interpretaciones conceptuales de Gaia y la Zona Crítica y las conexiones de estas interpretaciones con el concepto de lo Terrestre. Estos tres conceptos desempeñan un papel clave en el "giro político" que ha caracterizado la obra teórica más reciente de Bruno Latour. El análisis se desarrolla a través de las variaciones del concepto de habitabilidad en Gaia, Zona Crítica y Terrestre, empleadas como herramienta para captar los desplazamientos semánticos del campo científico-naturalista al campo político generados por los cambios que se han producido en los últimos veinte años en la forma en que las distintas ciencias de la Vida entienden la lógica de la habitabilidad del planeta Tierra. En el análisis se presta especial atención a las implicaciones, para la teoría social y política, que los cambios detectados con Gaia y Zona Crítica producen sobre las ideas de libertad y necesidad una vez que han salido de la dicotomía moderna naturaleza/humanidad y sobre la lógica de los conflictos que se abren en el horizonte de la Tierra.

Palabras clave

Latour, Gaia, Zona Crítica, Terrestre, Habitabilidad, Ecología Política, Clase Ecológica, Teoría del Actor-Red, Nuevo Régimen Climático.

In Latour's reflections over the last decade, three fundamental concepts - Gaia, Critical Zone and Terrestrial - have gradually, but not systematically, emerged and played a key role in the 'political turn' that has characterised his recent theoretical work. Each of them contains and mobilises a plurality of semantic fields and conceptual dimensions that allow and stimulate, sometimes clearly, sometimes more obscurely, unprecedented conceptualisations and crossings of boundaries between different scientific paradigms of the study of nature and between science and politics. To this polysemy is sometimes added a semantic uncertainty, which, while inevitable in order to sharpen one's gaze on the unprecedented, is reinforced by Latour's unsystematic use of these concepts, which can confuse the reader.

My intention in this paper is to show the relevance for social and political theory of some of the conceptual performances of Gaia and Critical Zone, highlighting the connections of these performances with the concept of Terrestrial, the most political-social of the three, introduced by Latour in Facing Gaia (2017a) and developed in subsequent works. In this analysis, the idea of habitability can serve as a thread, with the multiple implications that its meaning of "the set of conditions that make life possible in a given place or environment" sets in motion. "Habitability" problematises the scientific and political meanings of space and, above all, the normative conditions of its regulation in relation to the possibilities of life in that space, and can help us to grasp the semantic shifts from the scientific-naturalistic field to the political field generated by the fundamental changes that have taken place in the last twenty years in the way the logics of the habitability of planet Earth are understood by the various life sciences. These changes resonate strongly with the need for new concepts capable of illuminating and understanding the logic of those biogeochemical processes that challenge the modern paradigm of nature, of its habitability for all forms of life, and, no less importantly, blow up the normativity of the modern idea of nature - still in force in the distinction between organism/individual and environment - opening up to ideas of space and habitability that have strong political implications.

The concept of Gaia, formulated by Lovelock and Margulis in the 1960s and 1970s, long misunderstood and marginalised, revived and strengthened by a new interpretation by Latour and Lenton (2019), provides an epistemically relevant key to understanding the above processes. The concept of the critical zone addresses empirical-experimental and social science practices aimed at elaborating new concepts and new understandings of local configurations of the logic of habitability. Together, these two concepts indicate a profound shift in the notion of nature and non-human realities, which can no longer be thought in terms of the modern concept of nature, as is still often the case in socio-political interpretations of Latour's work. In fact, it is not a question of 'opening

up' or 'relating' to those non-humans who are modernly thought of as Galilean objects of a nature ontologically different from the social. The scientific discoveries of the last twenty years converge in revealing Gaian (or Lovelockian, as Latour sometimes calls them) objects and logics that pose unprecedented problems of conceptualisation and demands for new scientific practices in the life sciences debate, with significant political and social implications even for Critical Zone scientists.

The concept of the Terrestrial captures these transformations and invites a political thematisation of their habitability, starting with a rethinking of the conditions of human and non-human presence and the political implications of their regulation.

Gaia

In his research on the identification and measurement of polluting industrial gases in the mid-1960s, Lovelock took an innovative epistemic step by adopting a perspective from which, looking at the Earth from the outside - i.e. assuming a criterion of general and non-local validity of the still unknown processes he was trying to study - he asked himself how to identify and measure the transformative effects of the environment that any form of life on Earth could produce. Thus, both anthropogenic emissions and those produced by other life forms were placed on the same level. By asking how and to what extent life forms can modify the environment beyond the local level, it already initiates a move away from traditional conceptions of the order and regulation of nature, expressing a concern that anticipates the idea of the Anthropocene by a few decades. Even more significantly, by equating biotic activity with human industry, Lovelock conceives of biotic processes as free from dependence on a general or superior order, which ultimately directs its functioning according to an idea of nature as a plural reality, but integrated into its processes and consistent with the principles and/or primary factors of its own transformation - for example, natural selection of species, conceived as a universal process of adaptation to the environment, but with the capacity to modify it only locally.

With the development of this research and the elaboration of the concept of Gaia, Lovelock and Margulis (Lovelock & Margulis, 1974a; Margulis & Lovelock, 1974b), place themselves clearly in discontinuity with the conceptions of order and regulation that had long conceived of nature as a coherent whole, as a totality, whether initially in metaphysical and theological paradigms or, from the 17th century onwards, in mechanistic, organicist, cybernetic or other paradigms (Latour, 2017a). Despite their great diversity, the question of the relationship of the parts to the whole and the normative criteria of regulation that are assumed to be valid, i.e. philosophical, theological,

biological finalisms, laws of nature, determinisms and systemic processes, remain central in the idea of nature that they contain.

It is important to bear in mind that Lovelock does not start from a definition of what life is, or what Gaia is, but from the question of what life does, i.e. from what activities it is possible to derive information about life, in particular from what living beings do to the environment in which they live. For example, how they have transformed the atmosphere, creating the imbalance between methane and CO2 that makes it breathable, and above all, how they continue to maintain its composition in an imbalance that allows living things to continue. In his writings, Lovelock fluctuates considerably in his use of metaphorical meanings, making his argument unclear, but when he states that what has been thought of as the 'external framework' of life, i.e. the interconnected whole of the atmosphere, the oceans and the Earth's surface, is alive, he has no symbolic or metaphorical intentions; on the contrary, he means that this whole is not external to life, but a part of life.

Dutreuil (2020) pointed out an important difference between the current use of the term 'life' and Lovelock's use of it. The former refers to a class of which organisms are cases because they share necessary and sufficient properties, e.g. metabolic or evolutionary. Lovelock, on the other hand, uses it as a proper name to denote a singular entity: all the living organisms that have succeeded each other since the origin of life, not in terms of shared properties, but in terms of their own conditions of existence, and in particular asks how living organisms, through their own activity, influence and change their own conditions of existence. Lovelock's hypothesis is that Life - capitalised to denote the individual entity made up of the material ensemble of living beings that have succeeded one another since it appeared on Earth –

> at an early stage of its evolution acquired the capacity to control the global environment to suit its need, and this capacity has persisted and is still in use. (...) in this view the sum total of species is more than just a catalogue "The Biosphere," and, like other associations in biology, is an entity with properties greater than the simple sum of its parts (Lovelock, 1972, 579).

It is because of these sui generis properties - properties that are greater than the sum of the parts - that Lovelock sees Gaia as a singularity. In what non-metaphorical way can the set of all living things that have ever existed on Earth be thought of as an individual?

A first possibility is that practised by evolutionary biologists, who believe that biological species should not be thought of as classes (or natural types), but as individuals, and that individual organisms should be thought of as parts of the unified entity

'species', situated in space and time. The bond of union of the parts into an individual totality is identified in the genealogical continuity determined by descent. By virtue of this vertical link, species selection plays the role of both the logic of individual-species change and the general criterion for regulating natural change valid for all species.

However, Lovelock is not interested in this question of the relationship between the parts and the totality, but in the relationship between the activities of the life forms and what this activity does to influence and transform the living conditions of the life forms themselves. There is, in Lovelock's view, no supra-individual order or totality that would justify the sui generis character of this collective reality, not even in a metaphorical sense, there is a capacity for action, acted out collectively but not holistically, by the life entity, which is expressed in the transformation of the environment in favour of the conditions of existence of the life forms themselves.

It is a change of perspective from the current idea that the physiology of an organism is confined to the body of the individual and is separate from the environment in which it is found. When we look at the physiology of termites, for example, we see how in a termite mound the temperature and concentration of gases such as CO2 are controlled by the termites themselves, which can change the aeration and orientation of the termite mound, delineating an organic reality - defined by Scott Turner as the 'Extended Organism' - in which what we usually recognise as the 'inanimate world' is not merely a *habitable container* for living things, but a constitutive part of the organisms' own life processes. If we focus our attention on the conditions of existence of an individual, e.g. how a termite manages its vital needs for oxygen, CO2 and temperature, it is necessary to follow the flows of matter and energy that are absorbed and produced between the termite mound and the individual, crossing - both in the sense of production and in the sense of use - the covering formed by the termite's exoskeleton many times: The boundaries between the individual and its environment are thus blurred to the point where the entire termite mound is considered the material boundary of the termite-individual (Turner, 2000; Lenton, Dutreuil & Latour, 2020). It is precisely this connotation of vital extension that characterises the idea of Gaia as life interconnected with its environment, delineating a sui generis reality generated by heterogeneous agencies, neither integrated by general criteria nor reducible to primary factors (Dutreuil, 2020).

In Gaia, the organism loses the centrality that its identification with life has given it since the establishment of biology as a scientific discipline at the end of the 18th century, when the organism emerged as a category that held together the idea of a property common to all living things and the concepts of order and purpose associated with their development. Considering the 'environment' as an extension of living beings also implies the inclusion of geological realities in the study of biotic processes, and thus a focus

on processes on deep time scales - from thousands to millions or billions of years - and on measures of space calibrated to the scale of the entire planet and the size of the Inner Earth. The inclusion of geological time and space in habitability processes overshadows the time and space scales at which organisms and their activities are perceptible and meaningful.

It is the metabolic processes by which life forms modify and maintain their environment that emerge as the metamorphic extension of the living into the non-living. Of great importance in these processes is the fact that elements produced as waste from the metabolism of some life forms are recycled for the metabolism of other life forms, e.g. oxygen produced as waste from photosynthesis enters the metabolism of living species through aerobic respiration. This results in

> the organism ending up fully entangled in the consequences of the metabolism of its predecessors, thus creating a cascade of modifications. If we follow the cascade far and long enough, the idea that an organism resides in an untouched environment becomes ridiculous: what surrounds an organism are all the chemical transformations generated by all the other organisms living before and alongside it. Habitability is a joint venture (Lenton & Dutreuil, 2020a).

Although these processes of metamorphosis are numerous and complex, for the purposes of our analysis they can be metatheoretically grouped into three types of agency of life forms, each of which emerges in an apparent paradox (Lenton & Latour, 2018; Lenton & Dutreuil & Latour, 2020; Lenton & Dutreuil, 2020b).

The first type of agency appears in the paradox of a 'permanent disequilibrium': as mentioned above, the habitability of the atmosphere for life forms is not the result of a stable chemical equilibrium, but, given its composition of gases that react with each other by changing chemically, it is only possible under conditions of disequilibrium, which, however, is maintained over time. In fact, the proportion of oxygen must remain in the 17-25% range, but the presence of methane in the atmosphere reduces it by reaction. In addition, habitability also depends on maintaining the level of CO2, a greenhouse gas which, unlike other atmospheric gases that are rapidly eliminated by the atmosphere, has a residence time of between 300 and 1000 years and therefore tends to accumulate: it is known that at the beginning of the industrial age it represented only 0.0280% of atmospheric gases, whereas today it represents 0.0415%. In the absence of biotic activity, oxygen would gradually be reduced to a ridiculous level over billions of years, and CO2 would already have created a greenhouse effect that would make the Earth uninhabitable. The habitable atmosphere is therefore not an 'environment' prior to life, but the

unstable product generated and continuously maintained by biotic activity. With a ratio of 10,000 to 1 between biotic and abiotic activities, living things produce, discard and recycle oxygen in various metabolic cycles in which life forms are interwoven.

The second type of agency emerges from the paradox between the availability of energy and the proliferation of life forms. On the one hand, the abundance of solar energy on Earth is such that all the life forms that have succeeded one another over 4.5 billion years have captured only 1% of it and chemically transformed only 0.3; on the other hand, the availability of the elements necessary for the survival of living beings on Earth is very limited and does not allow their proliferation and expansion in space and time. So how can life forms proliferate? The disproportion between the number of ingredients available at the beginning and the immensely greater number of organisms today has been made possible by the autotrophy of metabolic cycles which, by recycling the waste products of other metabolisms, multiply organisms which, in turn, by entering into these cycles, increase the conditions of biotic existence. The cycles of use - production - consumption of the six elements fundamental to life - carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur - are for some, as in the case of phosphorus and nitrogen, entirely biological; for others, as in the case of carbon, the biological fluxes are some 400 times greater than the abiotic chemical-physical fluxes to and from the solid Earth (Latour, 2019). The agency of life forms is therefore the condition of their proliferation. It should be stressed that this agency is the result of processes that are not coordinated in a finalist sense, but are intertwined because they are interconnected and interdependent in a reticular form that multiplies the effects, allows the association of agents who, in turn, by expanding the network, distribute the activity by extending it, both in space and in time, without at any point closing it to the possibility of interference, modification and alteration.

The third type of agency emerges from the paradox that, despite its small size and very low energy consumption, the agency of vital activity, its influence and its effects are to endure over time, not passively but through its own activity. Latour calls this form of agency *historicity*.

The idea that the presence of liquid water is a necessary condition for the habitability of a planet is now common knowledge, made famous by NASA's space missions. On Earth, however, the presence and persistence of liquid water is not independent of biotic activity itself. Without the activity of living forms in retaining carbon in the rocks, the CO2 in the atmosphere would have gradually increased, causing the greenhouse effect and raising the temperature above 50°C, which in turn would have increased evaporation, which would have increased the temperature, which would have increased evaporation dispersing ever greater shares of hydrogen into space until there is no longer any

water on Earth. In other words, the existence of liquid water is not a mere fact, but an action in itself, acting through the chain of agents triggered by the metabolic work of living things on carbon. The persistence of liquid water over time is not a matter of mere availability, but an action that is continuously composed of the network of a plurality of actants activated by the metabolic fluxes of organisms. In short, water is not there, but it is kept there by chains that can be understood by following the action and its metamorphic links through biotic and abiotic actants.

Gaia is more than just Life, as it includes the effects of Life on its habitability conditions throughout the entire history of the Earth. What is crucial is that Life's action contributes to shaping habitability constraints from within feedback loops, therefore, it not only influences environmental variables, as it does the action of abiotic processes, but, unlike abiotic processes, it is sensitive to its own action, in the sense that the chains of which it is composed redistribute and amplify the feedback it receives from its own action. Without there being a Totality or a coherent order, it is this heterarchical dynamic that allows Gaia to *respond* to the feedback generated by its own action, decisively influencing the shaping of the conditions of its existence[1]. It is very well known that

> there would not be enough rain to maintain the Amazon rainforest without the actions of the forest itself: through evapotranspiration, bringing soil water up into the atmosphere, the Amazon rainforest contributes to maintaining the precipitation it needs to thrive. In the long run, therefore, plants have not *adapted* to a given climate: they have contributed to *maintaining* a climate in which they can persist (Lenton & Dutreuil, 2020, 173).

The multiple implications of these types of agency show that life forms are always situated within broader frameworks, and that these frameworks are partly generated and modified by biotic activity itself. The central point of the novelty introduced by Lovelock and Margulis "consists in granting historicity and agency to all life forms, that is, in attributing to the life forms themselves the task of creating the conditions for lasting in time and expanding in space. It is in that sense that they can be said to obey their own laws" (Latour & Lenton, 2019, 664). The great heterogeneity and heterarchic logic of Gaia's biotic processes prevent any reductionist attempt. The heterarchy of Gaia's metabolic processes also implies abandoning reduction to a spatial or temporal scale

1 For example, 'Life strongly amplifies the silicate weathering feedback on Earth today and by having organisms such as plants with narrower habitability bounds than 0°C-70°C entwined in the feedback loop, gives rise to narrower stabilising ranges. Furthermore, the biogenic weathering effect with plants may now be so strong that it could be maintaining Earth in a habitable state for plants when, without them, it would by now have become (or could soon become) uninhabitably hot for them" (Lenton, Dutreil & Latour, 2020, 261).

and keeping the analysis open to different scales and to a conception of a self-producing order that, by generating the conditions for its own continuation through its own forms of action, has no elements of necessity, remains open and unstable, differs in temporal and spatial scales, and does not subordinate the actors to a general principle. This lack of an integrated order makes it difficult to conceptualise, as scientists working on these processes have found, because there is a strong tendency to coordinate heterogeneous elements within a framework governed by cognitively coherent principles.

To achieve greater clarity, Latour calls for a move in the opposite direction: resistance to the addition of any further framework. At the same time, Gaia's heterogeneity is not chaos, but rather heterarchy, a plurality of orders that differ in scale and type of processes and cycles generated or mediated by life forms that are difficult to define positively and inappropriate to represent conceptually in a unified way as a totality (nature, superorganism, etc.). Gaia presents itself as a 'reticular, lacunar, dappled, distributed sort of entity', that makes its openness and precariousness a powerful resource in the absence of 'strong bonds'. This is particularly evident in life's use of free energy and the storage and processing of information: "If you look at energy transfer, life is barely visible; but if you look at the amount of new information and the fluxes of key biological elements, Gaia is everywhere and has modified the whole system - except it is not a 'whole system' " (Latour & Lenton 2019, 670).

This reticular entity cannot be an organism. In the first place, an organism is always in an environment with which it exchanges flows of matter and energy for its own survival; moreover, animal organisms are heterotrophic, i.e. they feed on organic matter; on the other hand, Gaia is autotrophic, because it produces itself with inorganic materials, or more precisely, photoautotrophic, since this self-production is powered by solar energy. Above all, Gaia carries out the vast majority of its exchanges internally, recycling many materials, while it carries out very limited exchanges of matter between the inner Earth (below the surface) and space. For these reasons, unlike organisms, Gaia has no exterior, no environment, understood as everything with which an entity enters into some kind of mutual relationship with others and as a source of resources for its own survival. In short, Gaia is her own environment (Lenton & Latour, 2018).

Secondly, as I have tried to show, the heterogeneity of the materials used in the biotic cycles and of the processes responsible for the cycles makes it impossible to speak of a coherent interior of Gaia, the heterogeneity of the biogeochemical cycles discovered over the years precludes understanding them in terms of a homogeneous biosphere. Indeed, the heterogeneity of transformation cycles makes the biotic/abiotic distinction, so important in Earth System science, much less meaningful than it was in the past. In rocks, for example, some solid mineral forms are produced directly by life (bio-miner-

alisation), some are indirectly due to life because they depend on oxygenation of the atmosphere, and some are entirely abiotic. Similarly, some gases are exclusively biogenic (isoprene, dimethylsulphide), many others are massively altered by life, and some do not interact with life (noble gases) (Lenton, Dutreuil & Latour, 2020). In short, the biotic/abiotic distinction cannot sustain a general criterion of regulation in Gaia. It makes sense, but in a necessarily nuanced, non-dichotomous way. This makes it impossible to speak of Gaia as a single entity, because it is composed of different material cycles, which differ in terms of the mediation carried out by living forms to maintain their biological function, and also in terms of the presence or absence of living forms as mediators. In fact, the intensity of the cycle will vary in relation to the needs of the life forms for their own survival: a high need will be met by a higher intensity of elemental recycling between life forms.

Thirdly, Gaia's heterarchy is not so much about the many elements mobilised in its cycles, but rather about the diversity of processes responsible for these cycles. The discoveries of the biogeochemical sciences in the last half century have made this point much clearer than the knowledge that may have existed when Lovelock and Margulis addressed this question. However, the fundamental point that justifies the absence of an intrinsic order of general scope and challenges the idea of totality is not so much the quantity of elements and processes that characterise Gaia, but the acquisition that "life forms produce their own extension in space and time" (Latour & Lenton, 2019, 671), i.e. their agency is not "located" in an a priori space and time external to it, but produces its own space and time in the way it extends and lasts (Latour, 2018). In the billions of years since its inception, Gaia has expanded both in the atmosphere and in the Earth's crust, generating and increasing its own conditions of proliferation.

The spatial extent of Gaia is influenced by different time scales, which define extremely heterogeneous types of agency and effects. For example, a short-term analysis of the feedback to intensive fossil fuel use unfolds in space between the atmosphere, the oceans and the Earth's surface, where life forms are located, down to the ground and underground. If we ask about long time scale feedbacks from the same analysis - for example, the influence of current climate warming in bringing forward the next glaciation (estimated at 100,000 years), or the presence and persistence of anthropogenic metals in sediments, rocks, the seabed, the inner Earth - then we have to change time and space scales, including exchanges with the crust and sedimentary rocks, and much longer time scales.

The residence time of elements in metabolic processes, the associations or couplings between elements and the strength with which they are more or less stabilised are important elements of Gaia's heterarchy. Different types of couplings, forces and

properties develop at different and intertwined spatial and temporal scales. Moving from one scale to another involves moving to different forms of self-generated order with varying degrees of stability/instability, persistence and expansion. At the local scale, for example, the cycling and recycling of nutrients within a forest is the result of a coupling that is reinforced by forms of natural selection that allow it to persist and even expand as the forest expands. At the individual scale, natural selection has perfected forms of homeostasis, such as human body temperature, that are highly effective but undetectable at other scales, such as the homeostasis of the atmosphere mentioned above. On a global scale, the coupling between living forms and climate is unstable, leading to greater uncertainty about their persistence, and thus difficulty in evolving, through natural selection, traits that favour persistence. Latour and Lenton show that on a biotic planet the possibilities for coupling and the development of evolutionary processes of different kinds are far greater than on a planet without life, testifying to the fact that life itself is a fundamental generator and multiplier of its own possibilities for survival.

Taken together, all these aspects break with the idea that nature is a homogeneous or integrated reality and show us that

> Gaia is a heterogeneous phenomenon created by the actions and interactions of many diverse biological free agents and aspects of their abiotic world, the result of which is a risky and provisional extension in space and duration in time (...) [Gaia] continually creates its own domain and behaviour through information and evolution, that is, through some sort of learning. What is observable is only the relative success of life forms in extending in space and lasting slightly longer in time-no more and no less. There is no guarantee of its continuity-no destiny superior to that of the life forms themselves. (Latour & Lenton 2019, 672)

Critical Zone

If in Gaia there is not a predetermined or finalistically self-determined order of Galilean objects, but a reality of many different biological free agents, then the heterarchy of its processes is not reducible to matters of fact and can be selectively composed through matters of concern (Latour, 2004) that mobilise communities from the research questions of scientists. In 1998, at a conference of the Geological Society of America, Gail Ashley introduced the concept of the 'critical zone', arguing for the importance of focusing on the interdependencies between the physical, chemical and biological

dimensions of life-critical processes that take place between the lower atmosphere and the barren rocks, i.e. in the vertical band around the Earth's surface, between 50 metres above the ground and below the ground to the barren rocks, from 30 metres to several hundred metres. Subsequently, in 2001, the National Research Council - USA initiated a funding project that led to the establishment of a few dozen Critical Zone Observatories between 2007 and 2020, to be reorganised as a system of hubs and clusters from 2021 onwards, in order to enhance both the development of research and the training of critical zone scientists (Brantley et al. 2017; Waldron, 2020).

"Critical zone" is a locally and thematically circumscribed, non-definitive way of redefining the object of scientific research from the interdependencies between different levels of biotic and abiotic processes. The study of interdependencies is always situated and determined by the local characteristics of the site. That is, it cannot be done in the laboratory, because the transformation processes of, for example, the minerals that form rocks are up to ten thousand times faster in the laboratory than in the field, where they can be slowed down and interrupted by the mobility of the elements and the variety of physico-chemical and anthropic conditions.

Unlike the objects of modern nature, abstracted from their secondary qualities, the intricacies of Gaia are not reproducible in laboratory abstraction. The difficulty of understanding them makes it difficult to conceptualise these processes and to define their spatial and temporal boundaries, but at the same time it opens up interdisciplinary modes of research previously excluded by the segmentation and specialisation of the various Life sciences.

The critical zone is thus configured as a space for segmentation of the Gaia entity, with the advantage of being able to capture situated interdependencies, placing analysis at a level very close to the 'experience' of non-humans and humans who 'inhabit' this critical zone. This space opens up possibilities for innovation in scientific paradigms and practices. The boundaries of the critical zone are defined horizontally in terms of the ability to obtain reliable data from research questions on the fluxes of activity of any of the agents whose actions - chemical, physical, metabolic or social - affect the present and future conditions of habitability of particular segments of the space occupied vertically by biotic activity between the lower atmosphere and the barren rocks.

In contrast to the container space of modern nature, which is occupied, dominated and controlled by the human subject as the only one endowed with agency, the critical zone is a reticular, heterogeneous and heterarchical space, structured by the agency of each actor in the network. It is the action that structures the space by connecting and disconnecting the actants, distributing agency and mediating it in distribution, extending or not the network in space and time: 'it is not the human we are considering, it is

the action' (Latour, 2014, 4). This means, for example, that the change in agricultural practices can be studied in its connections with changes in the nitrate and calcium content of the water at the mouth of a catchment area and the biodiversity in the area, and these can be linked to changes in the presence of tourists and their motivations as detected by the researcher, and finally the whole chain can in turn be linked at several points to the political-economic-administrative chain that brought EU subsidies to the area, mobilising and connecting other actors. One is thus outside the modern 'natural' space, which in classical geographical representation is stratified into ontologically defined levels, separating the 'physical' from the 'political', and these from the 'economic', and so on. This does not mean that in the network agency is always of the same intensity and effectiveness, and that there are not points of thickening or even hierarchisation. In fact, Latour has shown in many of his works, especially on technical-scientific innovation, that networks are not flat.

The logic of composition of this reticular form of research seriously allows connections to be made between the different carriers of knowledge in the critical zone, practising in a situated form the works of 'progressive composition of the common world' that Latour (2014, 3) defines as fundamentally political. In this sense, the qualification of the critical zone as 'critical' also contributes to the redefinition of space as a reality that is not stable or permanent, but exposed to the 'critical point', to the threshold beyond which change takes place or irreversible degradation begins, in whose web both humans and non-humans are caught, and in which the conditions of existence of the former are also indispensable for the latter. This networked, shifting, risky space defines a reality that can only be understood from within and that is very different from the 'territory' that is typically conceived and ordered from the outside by means of law or the distant and disinterested gaze of research; instead, critical zone researchers are themselves part of the space they study and contribute to making it visible precisely through the instruments of their research.

The visibility of the Critical Zone, that is to say, its being perceived first and foremost by those who are part of it, constitutes a very relevant aspect in the organisation of Critical Zone Observatories, because it extends the network, on the one hand, to the training of new Critical Zone scholars, through the creation of bachelor's, master's and doctoral courses that, by overcoming the disciplinary separations that still exist in universities, offer interdisciplinary training from the very beginning of university studies, without first having to teach separately what then needs to be rethought interdisciplinarily. This will produce an unprecedented generation of critical scholars who will bring truly interdisciplinary expertise to universities. On the other hand, the visibility of the Critical Zone is implemented through information/education

activities aimed at the inhabitants of the Critical Zone themselves, in order to increase awareness and responsibility, not towards a generic 'environment', but towards the dependencies that make their collective life possible and sustainable, and that need to be taken care of by the collectives of humans and non-humans as a matter of common concern for their mutual survival.

Partly a concept of locally declining gaian processes, partly an epistemically innovative organisational set-up of scientific research and training, partly a centre for information and promotion of awareness and responsible practices towards the inhabitants of the critical zone in relation to the dependencies that bind their community to the non-human actors of local biotic-abiotic processes, the critical zone introduces a significant change in the conception, definition and experience of space and its habitability, generating scientific, social and cultural practices and representations of the relationship between humans and non-humans.

Terrestrial

The concept of the Terrestrial brings together and thematises in a socio-political theory the key to the various meta-theoretical and empirical dimensions that we find in the concepts and practices of Gaia and the Critical Zone. Like, and perhaps more than, the other two concepts, both of which, for different reasons, are unsystematic, unfinished and open to revision as a result of new understandings, the concept of the Terrestrial seems to me to be even more marked by this incompleteness, which could border on incomprehensibility if one did not take into account its fundamental links with Gaia and the Critical Zone. The concept of the Terrestrial has been articulated in various ways by Latour in recent years (Latour, 2017a; 2018; 2022). However, it seems to me that certain dimensions are fundamental, which I will try to outline here in a necessarily schematic way, also for reasons of space.

First, the question of the relationship between necessity and freedom. In Gaia, necessity is not defined by a pre-existing order, but by the historicity of agency, i.e. the continuation of relationships in time and space according to laws generated by the agents themselves. Unlike nature, in Gaia we do not encounter

> the inflexible domain of necessity but, strangely enough, what is largely a domain of freedom, where life forms have, in some extraordinary ways, made their own laws, to the point of generating over eons multiple, heterogeneous, intricate, and fragile ways of lasting longer in time and extending further in space'. (Latour & Lenton, 2019, 679)

When nature is conceived as the realm of necessity, it becomes important to protect human freedom from the regulatory devices of society that are inspired by or based on the idea of nature, and to do so by making freedom an intrinsic property, ontologically exclusive to humans. However, the heterarchic and autotrophic nature of Gaia, and the consequent capacity to respond to human action, places us in a very different situation: that of the new climate regime, in which, more than in the past, we do not want nature to dictate human behaviour. But we can no longer avoid learning lessons from the way the Earth responds to human behaviour. As we have seen in the Critical Zone, the Earth's behaviour is a matter of concern to us, i.e. it is significant in defining our behaviour. This significance makes the Earth's behaviour 'political', not in itself, but for us, as it is, one might say with Weber, oriented to the attitude of others.

Gaia and the critical zone overcome the separation between the realm of necessity (i.e. nature) and the realm of freedom (i.e. politics and morality). The main consequence of the end of this separation is the redistribution of necessity and freedom between humans and non-humans. This repositions human and non-human forms of life in a way that is different from the rigid dichotomy that reciprocally paralysed humans and nature into predetermined and unchangeable positions, and which today shows its inadequacy in the face of the political effects of climate change. It is a political distance, made up of that mistrust, perplexity, enigmaticity, and mutability that seeks the - always provisional - settlement between behaviours in view of a common motive of concern (Latour & Lenton, 2019).

Secondly, the interdependencies that we have seen in Gaia and that in the critical zone become visible for those who study it and those who inhabit it, find in the concept of the Terrestrial the space for the elaboration of an idea of freedom that is not primarily identified with the forms of emancipation but maintains the link with the dependencies that make the living conditions of collectivities possible, including the practice of freedom. The exercise of freedom, in fact, never depends only on the legal-economic conditions available in an abstract space; the current Anthropocene condition makes dramatic the question posed already by Fichte and recently taken up by Charbonnier (2020): "What land does a community need in order to have access to the means of its emancipation?" The gulf between the world *in which* we live, the nation-state, and the world *from which* we live, the global economy, today traps the citizens of the rich West within nation-states that can no longer guarantee those conditions of freedom that were built at the expense of other peoples and other territories to allow the expansion of the production and mobility of consumer goods towards the West and the absorption of waste produced by the West (Latour, 2022). The limits of the planet and the new climate regime enter into this double movement, reversing into limits for all what were opportunities for some.

Thirdly, unlike nature, which guaranteed a higher order that was inaccessible to the social and political conflicts of which humanity was seen as the sole generator, Gaia does not guarantee order, and the conflicts are not only between humans, but also between humans and non-humans. For Latour, "landing on Earth" means becoming aware that we live on an Earth whose habitability is not only unstable, but will always be subject to and changed by the conflicting definition of the freedoms of its human and non-human actors. Thus, even for human survival, the planet has far more relevant and powerful capacities for action than resources for the 'development' of the industrial production system.

Capitalist production does not generate Life, but abstracts from the conditions of Life, assembling and combining, entangling, so that as it expands it captures and brings back all change, increasingly concealing from its agents the life-generating processes on which production obviously also depends.

The Terrestrial perspective extends the redefinition of human and non-human collectives to the connections generated by biotic processes, reducing the influence of production in the vital decisions of collectives. The timing and reproduction of collectives, when no longer subordinated to the rhythms and growth imposed by production, slow down and contract, anchoring the nexus between well-being and freedom in the conditions of existence of life itself. Modernity has decoupled this nexus, generating the two impossible promises of the infinite growth of production-profit and the infinite emancipation of the individual.

On this horizon, for Latour (2022), the political cleavage along which the fundamental conflict today is laid out is the distinction between those who want to narrow the space of relations of production, extending the collective to non-human actors, and those who want to preserve the centrality of production and its reproduction. This conflict separates, or will separate, the possible new "ecological class" from its opponents, which does not replace but complements the conflicts within the system of production. The transition to this dual level involves a redefinition of the ideals of freedom and emancipation in a context of dependency. The redistribution of freedom and necessity between humans and non-humans changes the meaning of emancipation, redefining it through the necessity of practising dependence on what makes us live.

The 'new ecological class', the addressee of Latour's latest book, could be the collective Terrestrial actor - brought into being by the conflicts generated by the current inability to respond to climate change - that introduces the perspective of anchoring the redefinition of the values of freedom and emancipation in the conditions of existence of life forms and the dependencies derived from them. By taking the redefinition of habitability as a privileged criterion, the ecological class finally meets its true owners. Ownership is not man's ownership of a world, but the world's ownership of man: it is the living

beings who, by definition, own themselves, because they have generated themselves out of themselves and, little by little, have generated the planet Earth through a process sui generis that has generated itself.

Nature is therefore not a victim to be protected: it belongs to us, and not in a symbolic sense. The challenge before us is to transform into common sense the idea that " 'I depend, and it is this that frees me, and I can therefore act", always bearing in mind that on the horizon of the Terrestrial, conflicts are neither temporary nor preliminary to a pacified order of man in nature (Latour, 2022, 16-20). Just as in Gaia there is no higher order that defines a habitability prior to the development of life, in Terrestrial there is no ideal of perpetual peace, not even utopianly understood as a regulative ideal, but a context of distributed freedom and necessity that always makes both conflict and integration possible, without this ineradicability of conflict having to be blamed exclusively on some negative anthropology.

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