

The problems of the Anthropocene in the Geologic Time Scale, and beyond

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Abstract

The formalization of the Anthropocene in the Geologic Time Scale (GTS) is a matter of debate. An assessment of the two current options, one formalizing the Anthropocene as an Epoch and the other considering the Anthropocene as an informal event in the Earth's history that does not require formalization, are critically analyzed. The focus of the analysis is on the philosophical issues underlying these two options, which make them unsatisfactory for addressing the occurrence of humans on Earth and the evolution of the relationship between humans and nature. Essentially, the approach followed by these options is non-historical, and does not undertake a research on the structural socio-economic roots of the Anthropocene. As a result, the concept of the Anthropocene is unable to identify the particular and historical form of *Anthropos* underlying the ongoing environmental degradation. Some inconsistencies in the current configuration of the GTS and in the rules for formalizing units inherited from the historical tradition of the GTS are also highlighted. The current dualistic approach of the Earth system science community, including the two options analyzed for the Anthropocene, prevents a proper understanding of the relationship between humans and nature, which is fundamental to confront the Earth's habitability crisis of the Anthropocene.

Keywords

Anthropocene, capital accumulation, economy, epistemology, formalization

Introduction

The formalization of the Anthropocene in the Geologic Time Scale (GTS) is one of the most controversial and fruitful discussions of recent years, going far beyond geology.ⁱ The debate has forced

geologists and Earth system scientists to look beyond their particular fields of research and incorporate human social activities into the current understanding of Earth dynamics. In turn, social scientists have been forced to delve into disciplines of the natural sciences that lie outside the realm of the social sciences. This is not surprising, since the Anthropocene and its formalization in the GTS requires a comprehensive understanding of the Earth as a natural system, together with the role that humans and their modes of social organization play in modifying that system. Thus, although geology, earth system science, economics, philosophy, and all the various disciplines of the natural and social sciences have their own methods and subjects of research, the Anthropocene cannot be properly understood unless the knowledge of these disciplines is integrated into a unified theoretical corpus in which observed phenomena are causally related to the deeper structural determinations of the system. The formalization of the Anthropocene cannot be fully divorced from what the Anthropocene means: an ongoing crisis of habitability that is unique in Earth history for two main reasons. Because it is driven solely by human activity, and because the processes of environmental degradation are occurring more rapidly than in similar crises in the geological record.

Studies of the Anthropocene have, for the first time in human history, opened up the possibility of consciously acting within the Earth System on a global scale and on a scientific basis in order to keep the planet habitable. In terms of formalization, prior to the Anthropocene, GTS units were typically formalized once the stratigraphic content - from which the Earth's history is inferred - was reasonably well known. This has changed with the Anthropocene, and a new methodological approach to our understanding of Earth history and to the formalization of units in the GTS has been inaugurated. From an epistemological perspective, the understanding of Earth's history first proceeded from data observed in local strata to the inference of global phenomena, whereas now in the Anthropocene it proceeds in the opposite direction, from global phenomena to their expression in local strata. As a result, the human-induced planetary crisis we are now currently facing has not been known from strata but from global environmental indicators. Regarding formalization, this means that the planetary crisis

is being sought in strata rather than being inferred from strata. The rationale behind this procedure is that if we know from the geologic record of previous planetary crises similar to the present one, it is reasonable to hypothesize that a stratigraphic signature of the ongoing planetary crisis can be found. Although the search for empirical evidence of theoretical knowledge is quite common in science, this procedure poses some problems in terms of formalizing the crisis in the GTS, because historically, events in Earth history have been inferred from the geological record, and so the formalization of units in the GTS reflects this methodological procedure.

The debate about the Anthropocene has intensified in recent years as the date of the formalization proposal developed by the Anthropocene Working Group (AWG) approached. Finally, the AWG submitted the proposal to the International Commission of Stratigraphy (ICS) in October 2023, but the debate is still open.ⁱⁱ In essence, two opposing views on the formalization of the Anthropocene have been delineated over the past few years. The AWG supports to formalize the Anthropocene as the last Epoch of the Quaternary Period following the Holocene. The proposed Global Boundary Stratigraphic section and Point (GSSP) of the Anthropocene Epoch is hosted in varved sediments of Crawford Lake in Ontario, Canada. The primary stratigraphic markers are ^{239}Pu and ^{14}C radionuclides deposited from nuclear weapons testing during the 1940s and 1950s, which give an starting date for the Anthropocene Epoch in the mid-20th century. Opponents to the Anthropocene formalization in the GTS argue that the Anthropocene should be considered an event of the Earth history like, for example, the Great Oxidation Event in the Proterozoic, the Great Ordovician Biodiversification, and others. Since events are informal units that do not require standardization in the GTS, this option in practice rejects the formalization of the Anthropocene.

This contribution critically reviews the main issues raised by the two opposing views on the formalization of the Anthropocene. The goal is not to question the excellent research in Earth system science and Anthropocene studies that has significantly improved our current understanding of Earth dynamics. Rather, it is to point out some problems with the formalization of the habitability crisis in the

GTS, which ultimately relate to the conceptual understanding of this crisis. Since most of the disagreements about the Anthropocene and its formalization have an epistemological, i.e. philosophical, basis, and since philosophy is rather neglected in current studies of the natural sciences, the importance of philosophy, and in particular of epistemology, for the natural sciences is first emphasized. Then, a specific critique of the two opposing views on the formalization of the Anthropocene is undertaken. The epistemic flaws underlying these views, and Anthropocene studies in general, and some current inconsistencies of the GTS regarding the rules for formalizing units are highlighted.

Why philosophy can help in the dispute over the formalization of the Anthropocene

Many of the disputes in the natural sciences about various issues throughout history have an epistemological basis in the background. For example, the crisis of modern physics at the beginning of the 20th century, in which the possibility of motion without matter, and thus the disappearance of matter, was considered, and led some notable physicists like Poincaré to conclude that “it is not nature which imposes on [or dictates to] us the concepts of space and time, but we who impose them on nature”; “whatever is not thought, is pure nothing” (quoted in Lenin, 1972). Lenin corrected Poincaré for his idealistic view and, following Engels, provided a materialist and monist understanding of the dialectical unity of matter and motion. Later on, during the Bohr-Einstein debates about quantum mechanics, Einstein declared that “he would have liked ‘old Spinoza’ as the umpire in his dispute with Niels Bohr on the fundamental problems of quantum mechanics rather than Carnap or Bertrand Russell, who were contending for the role of the ‘philosopher of modern science’ and spoke disdainfully of Spinoza’s philosophy as an ‘outmoded’ point of view ‘which neither science nor philosophy can nowadays accept’” (Ilyenkov, 1974). The reason for Einstein's preference for Spinoza was his truly materialistic approach, as opposed to the idealistic and positivistic understanding of

Carnap and Russell. More recently, the debate about the feasibility of the so-called Gaia hypothesis or theory has brought to the fore questions such as whether there is any kind of conscious or unconscious teleology in nature, and what are the limits of empiricism for validating theories (Lenton, 1998; Kirchner, 2003; Bondi, 2015; Janković and Ćirković, 2016). Other questions raised, such as what are the units of natural selection, whether individuals and taxa or metabolic and developmental interaction patterns, resemble the matter versus motion debate in early 20th century physics and cannot be properly addressed from a dichotomous perspective, but only from a monistic understanding (Doolittle and Booth, 2017).ⁱⁱⁱ

In summary, these are just a few examples to illustrate how philosophy can provide the right focus to solve problems and dilemmas that the natural sciences usually face in the study of natural phenomena. Modern Earth system science and Anthropocene studies are no exception, and they cannot neglect philosophy in the face of the problems that human societies pose for the understanding of nature, including those related to the formalization of the Anthropocene. As stated by Valery Bosenko, these are “philosophical questions of physics, philosophical questions of biology, etc., in short, the philosophical questions of the natural sciences. These are solved by naturalists themselves (and not by philosophers) *with the help of* philosophy. For this, the naturalists wield (they must necessarily take up) the philosophical weapons, the materialistic principles, dialectical principles, mastering dialectical theoretical thinking (*creating it each one by himself*), dialectical logic, gnoseology, etc.” (Bosenko, 1965, emphasis in the original. English translation from Spanish by the author).

Analysis of the formalization proposal by Anthropocene Working Group

The Anthropocene is the term chosen by the AWG to identify the Epoch of GTS in which human activity is causing a major shift in the conditions of Earth's habitability relative to the conditions of the Holocene Epoch. The AWG borrowed the term Anthropocene from Crutzen and Stoermer (2000)

and Crutzen (2002), and in doing so, the AWG also borrowed the conceptual content underlying the term, a content that has been rather vague and ambiguous from the beginning. For example, “During the Holocene mankind’s activities gradually grew into a significant geological, morphological force, as recognised early on by a number of scientists”, and “The expansion of mankind, both in numbers and per capita exploitation of Earth’s resources has been astounding” (Crutzen and Stoermer, 2000). From these and other similar statements, it is clear that Crutzen and Stoermer did not recognize a differential contribution to global environmental degradation by different social classes and different modes of human social organization throughout history. Regardless of whether Crutzen and Stoermer identified the late 18th century as the time of a significant departure of human impact on Earth, and whether the AWG later refined this time to the mid-20th century on the basis of the Great Acceleration Array Event (GAEA in Waters et al., 2022), the fact is that the AWG has so far maintained the term Anthropocene, which vaguely attributes the Earth's habitability crisis to an abstract anthropos, rather than to a concrete and historically determined anthropos. Namely, to the capitalist anthropos organized under a concrete regime of social reproduction consisting of the accumulation of capital through the production of commodities, which has become global in a historical process of several centuries. The AWG claims for the precision and accuracy of the terms and concepts in science and in the GTS: “The advance of science is best served through clearly developed concepts supported by tightly circumscribed terminology; indeed, improvements to stratigraphy over recent decades have been achieved through increasingly precise definitions, especially for chronostratigraphic units, and not by retaining vague terminology” (Waters et al, 2023a). It is difficult not to agree with this statement. However, by proposing the term Anthropocene with its ambiguous conceptual connotations, the AWG not only fails to identify the fundamental *causa finalis* underlying the ongoing habitability crisis, but also fails to follow its own principles. Note that attributing the beginning of the Anthropocene to the invention of the steam engine in 1784 or to the GAEA in the mid-20th century fails to identify the essential roots of this crisis, which are ultimately economic. Such an attribution can be made simply by correlating two

sets of empirical data, namely the environmental indicators and the socio-economic indicators, but establishing the concrete relationship between these data sets in terms of causality and necessity is another issue, which requires further research that has not been undertaken by the AWG. This research would have made it possible to go beyond the direct links observed between environmental and socio-economic phenomena, such as between CO₂ and the burning of fossil fuels, and to reveal the structural socio-economic roots of the Anthropocene crisis. It would have made it possible to understand why the particular unfolding of these links is historical and a necessity of a given socio-economic system that cannot be overcome within the limits of the system (e.g. Chen, 2017; Foster, 2022).

Given the ambiguity implicit in the concept of the Anthropocene since its inception and the uncritical adoption of the Anthropocene by the AWG, it is understandable that other terms have been proposed to resolve such conceptual ambiguity. For example, Capitalocene has been proposed instead of Anthropocene to name the new Epoch of the GTS, and Capitalian or Capitalinian has been proposed to name the lower Age of the Anthropocene Epoch (Malm, 2016; Soriano, 2020; Foster, 2021). While these proposals may not follow the ICS recommendations for formalizing the units of the GTS, the relevant feature is that they have been formulated as demands to adopt more precise conceptualizations of the current habitability crisis on Earth. In terms of GTS nomenclature, the Capitalocene has similar problems to the Anthropocene. Etimologically, the Anthropocene stands for “new or recent *Anthropos* or human”, but an “old or less recent *Anthropos*” is missing in the GTS. Similarly, Capitalocene stands for “new capital”, but an “old capital” is also lacking in the GTS. Moreover, although the dominant forms of capital may have changed throughout history, this is only a formal change, while the essence of the mode of social reproduction based on capital accumulation through commodity production has remained the same. As for Capitalian or Capitalinian, these terms would break with today's consistent nomenclature of the lowest chronostratigraphic units of the GTS, which derive their names from the names of geographic features near the stratotype area of the GSSP. This nomenclature has been correctly followed for the candidate sites to host the GSSP of the Anthropocene Ages (Waters et al.,

2023b). In any case, the introduction of Capitalocene and Capitalian or Capitalinian would imply a profound conceptual modification of the GTS, because for the first time a specific mode of production of human history would be specified. Nevertheless, this is a direct implication of the Anthropocene epoch itself, where a concrete way of understanding the relationship between natural and social history specific to the AWG proposal is implicit, albeit ambiguous.

Analysis of the Anthropocene as a diachronous event in Earth history

The main objection to the formalization of the Anthropocene as proposed by the AWG is that it does not reflect the time-transgressive nature of human impact on the Earth. In particular, it “fails to account not only for the diachronic nature of human impacts on global environmental systems during the Late Holocene but also the spatial heterogeneity of those impacts” (Walker et al., 2023). As a result, the Anthropocene should be understood as “the aggregated effects of human activities that have transformed, and continue to transform, the Earth system and influence biodiversity, thereby producing a substantial, characteristic and unique record in sedimentary strata and in human modified ground” (Gibbard et al., 2022). There can be no doubt about the time-transgressive nature of the human impact on Earth, nor about the stratigraphic record of that impact. However, that is not the issue addressed by the AWG proposal. This proposal identifies a sudden jump in human impact based on the empirical data shown by the GAEA. It is a departure in human impact on the Earth that has no quantitative precedent in human history. Such a departure has a stratigraphic expression widely documented in the studies conducted by the AWG, and it also has well-documented stratigraphic markers suitable for synchronous correlation worldwide, which are the basic requirements of the ICS to define new units of the GTS based on the GSSPs. The proposal of the Anthropocene as a diachronic event in Earth history nullifies, or at best dilutes, the robust evidence of empirical data on the quantitative leap in human impact around the mid-20th century.

Philosophy can shed some light on a better understanding of the Anthropocene. The quantitative departure of the human impact on Earth can be best understood with Hegel's law of dialectics of reciprocal transformation between quantitative and qualitative changes in the general motion of matter. For example, a solid undergoes a qualitative change to a liquid after a quantitative increase in its temperature. The quantitative change in human impact in the Anthropocene is based on the qualitative specificity of the capitalist mode of social reproduction with respect to earlier modes of social production in human history, which did not produce such a quantitative leap. Understood in this way, the quantitative change of the Anthropocene marks a turning point in the relationship between humans and nature, without comparison to previous forms of this relationship. A turning point that has its origin and subsequent development in the particular type of social metabolism with nature that is governed by the reproduction of capital rather than by human beings themselves (Foster, 2022). Following Hegel, Marx stated "all science would be superfluous if the outward appearance and the essence of things directly coincided" (Marx, 2010). This means that phenomena and essence do not necessarily coincide, and for this reason scientific research is needed to characterize the concrete mediations between phenomena and essence. As a general principle, phenomena and essence constitute a dialectical unit in which observed phenomena appear shaped by multiple mediations of underlying essence, in which phenomena may even appear as opposite of essence (Saosorov, 1960). For example, the Sun seems to move around the Earth, but scientific research has shown that reality is just the opposite. An earthquake is the phenomenal expression of plate boundary friction, which is the essential determination underlying the phenomena, and it is mediated, for example, by local fluid pressure, which may result in earthquakes of different magnitudes, fault ruptures, etc.^{iv} The essential and structural *causa finalis* of the Anthropocene major shift in Earth dynamics is the contradiction inherent in the reproduction of capital as governed by its constitutive laws. This essential contradiction is expressed in environmental indicators and in strata, which are its phenomenal expressions mediated by the laws or principles of biological processes, the physics and chemistry of the atmosphere, and the principles of geology, such

as Steno's law of superposition of strata. Moreover, the dynamics and history of capitalist production, including the class struggle inherent in this mode of production, also mediate the phenomenal expression of the essential capitalist contradiction. For example, social pressure against harmful effects on human health and on environment may force the abandonment of the production of a given commodity, and hence modify its stratal expression. All these mediations explain the diachronicity of the phenomenal expressions, both environmental and stratigraphic, of the Anthropocene shift within the history of capitalist production, even though the bulk of indicators show a major break around the mid-20th century.

The formalization of units in the GTS and some options for the Anthropocene

The GTS has been compared to the Periodic Table of Elements (PTE), but it is more complex (Rull, 2017). The PTE reflects the structure and motion of matter at the lowest stage of matter evolution, while the GTS deals with the evolution of matter from the stage of inorganic matter to the evolved stages of organic matter and to the various evolutionary stages of living organisms. Each new stage in the evolution of matter assimilates at its core the laws or principles of the earlier stages, which appear in new forms and mediate the observed phenomena of the evolved stage (Rubinstein, 1963). By attempting to formalize the Anthropos, the GTS is addressing the last stage in the evolution of matter, the stage in which matter has evolved into intelligent matter and all former laws and principles are subsumed under the laws of human social reproduction. Before the development of evolutionary biology in the 19th century, the monistic and materialistic perspective of Baruch Spinoza allowed him to conclude that thought is an attribute of matter and that humanity is the thinking body of nature, a thinking body that thinks about the rest of nature and about its own process of thinking. It is therefore understandable why addressing the Anthropos in the GTS is such a complex issue.

The origins of GTS can be traced back to the 18th and 19th centuries, coinciding with the development of most of the natural sciences during the modernity. The GTS is under constant revision and is evolving roughly in line with our understanding of Earth history. Initially, chronostratigraphic units were characterized by the approximate position and duration of their stratotypes, whose definition was usually based on their fossil content and sometimes were merely facies types with local distribution. In the late 20th century, GSSPs were designed to overcome the inherent limitations of local stratotypes, favoring global correlation and continuous stratigraphic record. Traditionally, the names given to chronostratigraphic units in the GTS nomenclature have tried to stay as close as possible to mere descriptions, usually avoiding too much interpretation of Earth history. The rationale for this option is based on the instrumental and practical nature of the GTS, that is, the fact that the GTS is an agreed-upon correlation tool to which Earth history is referred, but it is not Earth history *per se*. It is true, however, that especially after the introduction of the GSSP requirements for the formalization of units, this tool serves in practice for the direct correlation of events in Earth history. Nevertheless, the content of the names of most chronostratigraphic units is usually quite close to the etymological content of the term. For example, most names of Eons and Eras account for the chronological presence of life in strata on a descriptive basis: Paleozoic (old life), Mesozoic (intermediate life), Cenozoic (new or recent life), Phanerozoic (visible life), Proterozoic (earlier life). According to the descriptive nature of the GTS and following recommendation of the ICS, Ages—the lowest rank hierarchical chronostratigraphic units of the GTS—compose their names with the names of geographical features near the stratotype area of the GSSP and “-ian” or “-an” endings.^v This is an ICS recommendation for Epochs, too, although it has not been followed for most Epochs of the Cenozoic Era. For example, Holocene stands for “entirely new or recent”, Pleistocene for “newest”, Pliocene for “newer”, Miocene for “less new”, Oligocene for “few new”, Eocene for “dawn new” and Paleocene for “old eocene”. The names of Cenozoic Epochs, and of the Cenozoic Periods except the Quaternary, refer ultimately to the successive appearances of life in strata following the Cretaceous-Paleogene mass extinction at about 66

million years ago, and they were mainly coined by geologists of the 19th century. For example, Charles Lyell gave the names of the Pliocene, the Miocene, and the Eocene.

The complexity of addressing the Anthropos in the GTS, together with the weight of tradition in naming units and some philosophical misconceptions, has led to some inconsistencies in the current configuration of the GTS and in the AWG proposal for the Anthropocene. Although it is probably time to have consistent nomenclature guidelines throughout the GTS, and to actually follow them when naming units, currently only Ages, Eons, and Eras have consistent nomenclature, but not Epochs and Periods. It has been rightly suggested that, as a general principle, the rules and criteria necessary to formalize and name chronostratigraphic units should be as consistent as possible throughout the GTS (Luciano, 2022). Claims that the names of some Cenozoic units are already well established and have a long tradition are not really arguments, or at least not scientific arguments, for keeping them in the GTS. Other terms, like the Tertiary Period or the Secondary Era, were also once well established too, but they have been abandoned in the GTS nomenclature in favor of other terms—in particular regarding the nomenclature of Eras—that more accurately reflect the Earth’s history without betraying the essentially descriptive nature of the GTS. The current dual nomenclature of International Chronostratigraphic Chart (ICC) names and GTS names has been claimed to be impractical in many cases and should be overcome (Harland et al., 1990; Hilgen et al., 2006; Gradstein et al., 2012; Zalasiewicz et al. 2017). Such a dualism is based on a wrong philosophical foundation regarding the concepts of matter and time. The ICS states that “Chronostratigraphic units [of the ICC] are tangible stratigraphic units because they encompass all rocks comprised between two bounding chronostratigraphic horizons, i.e., horizons believed to be readily correlatable worldwide” and “Geochronologic units [of the GTS] are units of *time-an intangible property-and thus intangible units, not in themselves stratigraphic units*” (see <https://stratigraphy.org/guide/princ>, emphasis mine). From a materialistic and monistic point of view, this separation does not make much sense, for time is matter in motion, and there cannot be time without the motion of matter, so time is fully tangible, as are

geochronological units. Certainly, matter and time must be distinguished as different categories of reality reflected in thought, but in an essentially practical tool like the GTS, this distinction may not be necessary.

Resolving the inconsistencies of the GTS nomenclature is beyond the scope of this contribution. This task should be addressed within the ICS, possibly by a specific commission or subcommission with this particular mandate. However, in suggesting some options for formalizing the Earth habitability crisis, references to some current GTS inconsistencies reproduced by the AWG proposal are unavoidable.

The AWG proposal follows the descriptive methodology of the GTS, as well as the current practice of naming Cenozoic Epochs. In this way, however, the AWG does not follow the ICS recommendation for Epochs of the GTS, as is the case for the Guadalupian, Terrenuvian, and others. Following this recommendation would imply giving the name of a local geographic feature with an “ian” or “an” ending. For example, an Ontarian Epoch and a Crawfordian Age based on the candidate site selected by the AWG to host the GSSP of the Anthropocene. However, the name Ontarian would be in sharp contrast to the current names of Epochs in the Cenozoic. For the sake of consistency in the GTS nomenclature, this option would require revision of other names of Epochs in the Cenozoic, Mesozoic and Paleozoic Eras, if not in the short term at least as a task to be undertaken with subsequent revisions of the GTS. At present, it is not clear whether the successive appearances of life in strata should be described at the hierarchical level of Eons and Eras or whether this description should include Periods and Epochs, as is the case for most of the Cenozoic. The GTS is an agreed convention, so if the ICS agrees that Periods and Epochs should reflect the appearances of life, the conceptual ambiguity of the term Anthropocene could be partially resolved by replacing the current Quaternary period with Alexei Pavlov's Anthropogene, based on the emergence and evolution of the genus *Homo* on Earth (Gerasimov, 1979). These criteria could serve as the basis for reformulating the Anthropozoic of Italian geologist Antonio Stoppani and define it as an Era following the Cenozoic and starting at the

base of the Gelasian Age (Rull, 2020). If the ICS agrees to disregard periods and epochs in describing the appearances of life on Earth, then the names of Periods and Epochs in the Cenozoic should be revised.

Epistemic flaws underlying the concept of the Anthropocene

The Anthropocene has been misconceived within Earth system science studies because research on the fundamental socio-economic roots underlying the major Earth change of the Anthropocene has been neglected. As Anthropocene researchers clearly acknowledge, the Anthropocene is a concept that emerged from the Earth system science community. From the beginning, the term Anthropocene implicitly identified, perhaps inadvertently for Earth system scientists, the great Earth shift to a general Anthropos rather than to a particular and historical form of Anthropos, as it must if the Anthropocene shift is to be understood on a scientific basis and, more importantly, if the crisis of Earth habitability associated with the Anthropocene is to be addressed on a scientific basis. Due to the lack of research on the deep socio-economic roots of the Earth shift, Anthropocene scholars have been forced to develop a rather dichotomous understanding of the Anthropocene. On the one hand, it is understood as a merely technical issue regarding the GTS and the Earth system science, which has led the Earth system science community to conceive of a “scientific” Anthropocene placed at the “analytical level” and allowing for a “very precise, strict understanding”. On the other hand, the Anthropocene is understood as a less precise issue that “begets criticism and debate”, corresponding to the humanities and social sciences, and placed on the non-scientific “consequential metalevel” with respect to gnoseology (See Fig. 3 in Zalasiewicz et al., 2021).

The dichotomous understanding of the Anthropocene by Earth system scientists, including those who support formalization and those who oppose it, is an expression of the old dichotomous understanding of the natural and social sciences, in which both fields are approached through different

epistemic paradigms. Such a dichotomy needs to be transcended if the habitability crisis of the Anthropocene is to be transcended too, but it is impossible to transcend with the current dualistic approach of Anthropocene studies and Earth system science (See Soriano, 2022). First, because this dualistic view negates in practice the scientific character of the social sciences, as if social history could not be approached from the objectivity of facts and analytical categories, but only from the subjectivity of individuals. That is, for this dualistic view, social history cannot be understood scientifically on a materialist and dialectical basis, as natural history is, regardless of whether natural scientists are unaware of the epistemological basis on which nature is understood. This demonstrates the importance of being aware of the epistemological basis for understanding reality. This view condemns social history to the eternal disagreements of different opinions on a given subject because of the lack of objectivity and scientificity of the approaches followed, and seems to forget the innumerable disputes in the field of natural sciences along history, which, as shown above, always have a philosophical basis and political implications. Second, because the relationships between the various subfields of the social and natural sciences, which are represented as arrows in the so-called “integrative and extended multilevel Anthropocene concept” diagram and in the Bretherton diagram, are merely formal (See Steffen et al., 2020; Zalasiewicz et al., 2021). In other words, these relationships are devoid of any essential causal concatenations other than the immediate cause and effect relationships that can be directly observed in phenomena. Third, in terms of the habitability crisis, Anthropocene scholars understand the relationship between the social and the natural upside down. Thus, the social is not at the “consequential metalevel” as Anthropocene science claims, but just the opposite. Being synthetic, the habitability crisis of the Anthropocene is ultimately underpinned by the structural and causal mechanisms of capital accumulation at a declining rate of profit, and for this reason the crisis is an expression of the fundamental contradiction inherent in the capitalist mode of social reproduction (Soriano, 2022). Although it is true that the habitability crisis has consequences in economy, politics, philosophy and so on, this is a mere description of ongoing facts in a rather

mechanistic cause-and-effect way, while the lack of research aimed at investigating the ultimate and fundamental determinants of the crisis in the end leads to its misunderstanding.

The relationship between thinking and being is the cardinal problem of philosophy, which has taken different forms throughout history, like the relationship between the natural and the social (Engels, 1946). The dualistic conception of Earth system science does not allow for the resolution of this problem, which is central to a proper understanding of the habitability crisis. Understanding this crisis is only possible from what Marx and Engels called one science, the science of history, in which the social and the natural are concretely intertwined, not only at the level of immediate phenomena, but at a level where the essence of the crisis is fully revealed (Marx and Engels, 1974). Only a dialectic and materialist monistic approach to the relationship between nature and society can show that the crisis of habitability on Earth is driven by a socio-economic system based on the reproduction of capital, carried out by humans without a conscious understanding of the laws governing the social system (Soriano, 2018). Following Spinoza's monistic materialism enriched with Hegelian dialectics, Marx realized that the historical time of only one science was yet to come, and that farther development of both natural sciences and social sciences was needed before they could become a single science of history: "History itself is a real part of *natural history*—of nature developing into man. Natural science will in time incorporate into itself the science of man, just as the science of man will incorporate into itself natural science: there will be *one science*" (Marx, 1959, emphasis in the original). Nearly two centuries after Marx's assertion, the unified science of history is still to come, but it has now become an urgent task if Earth is to remain a habitable planet.

Conclusions

Humanity is the last stage in the evolution of matter on Earth. The formalization of humanity in the GTS is a complex issue that requires consideration of philosophical questions, such as thinking

about the process of thinking and the role of humans on Earth. Philosophical issues cannot be left aside when considering the formalization of humans in the GTS. The Anthropocene has recently been submitted to the ICS for formalization as the last epoch of the GTS after the Holocene. There is still a debate between the AWG responsible for this proposal and researchers who consider the Anthropocene to be a diachronic event in Earth history that does not require formalization. The main problem for formalization is the ambiguity of the term Anthropocene, which attributes the habitability crisis of the Anthropocene to a general Anthropos rather than to a historical and concrete Anthropos, namely a capitalist Anthropos. Such ambiguity is ultimately due to the ambiguous conception of the relationship between humanity and nature. It is therefore epistemological in nature. Scientists who reject formalization have not properly grasped the quantitative leap in human impact on Earth based on the qualitatively different form of human social organization of capitalism. Marx's concept of the relationship between essence and phenomena helps to understand how the fundamental socio-economic roots of the habitability crisis of the Anthropocene, namely the reproduction of capital, do not coincide with the manifestation of the crisis in environmental parameters and in strata.

Scientists in the Earth System Science community have not conducted research aimed at understanding the internal contradictions of capital accumulation and their relationship to the crisis of Earth's habitability. This research allows us to see this crisis as a manifestation of the fundamental contradiction of capital accumulation, a contradiction inherent to the capitalist system that cannot be overcome within the limits of this mode of social reproduction. Such a research is only possible if the excellent studies on the Earth's dynamics are coupled with studies on the fundamentals of capitalist production on a monist, dialectical and materialist basis. Today, the prevailing dualistic view of nature and society does not allow the essential contradiction of the system to be revealed, and nature and society remain connected only at the phenomenological level of cause and effect.

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- i The GTS is a geochronological framework based on the units of the International Chronostratigraphic Chart, which are named after physical strata and are anchored to a linear time scale in the GTS (see Soriano, 2020; Finney and Gibbard, 2023). For simplicity, only the names of the units in the GTS will be used here.
- ii Approval of the proposal involves several steps within the hierarchical organization of the International Union of Geological Sciences (see Rull, in press).
- iii The references given here are just a few examples of the debate about the Gaia hypothesis.
- iv This is only a schematic example to illustrate the relationship between essence and phenomena in geology. Things are more complex and there are other factors involved that are not considered here.
- v See <https://stratigraphy.org/guide/chron> for ICS guidelines on formalizing units.