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Critical Zone

- Jeanne Etelain

Abstract

This article examines the concept of Critical Zone – the skin of the planet Earth where rock meets life – that has recently emerged from the geoscience community. Outstanding research opportunities related to the ontological and epistemological problems of the Critical Zone also warrant expansions into artistic, anthropological, and political inquiry, while raising some significant philosophical questions about the space of the Earth and the human.

We have entered the Anthropocene, human activities transforming the Earth System itself. Global warming puts more and more pressure on the Earth's surface that supports nearly all terrestrial life, the human species, and our societies. Most of the life-sustaining processes and all living things exist in a narrow band close to the surface of the planet. Scientists have named this sensitive area the Critical Zone (CZ). In 2001, the US National Research Council (NRC) elected the study of the CZ as one of the most compelling research areas in Earth sciences in the twenty-first century. The NRC defines the CZ as the “heterogeneous, near surface environment in which complex interactions involving rock, soil, water, air, and living organisms regulate the natural habitat and determine the availability of life-sustaining resources” (2001, p. 2). Brantley et al. provide an alternative definition of the CZ as “the fragile skin of the planet defined from the outer extent of vegetation down to the lower limits of groundwater” (2007, p. 307).

The CZ, a term first introduced by the sedimentologist Gail Ashley (1998), is the thin outer veneer of the planet Earth's surface, lying between the sky and the rocks, that is the seat of life. It encompasses the lower atmosphere, vegetation canopy, water bodies (rivers, lakes, shallow seas), soil layers (pedosphere, vadose zone, the water table), and fresh groundwater. It is a porous medium resulting from interactions between biogeochemical-physical processes animated by solar energy, the transformation of minerals in contact with gases giving birth to the land surface, the water cycle, and the living beings which populate Earth. Coterminal with the Gaia Hypothesis invented jointly by the geochemist James Lovelock and Lynn Margulis (1974), it is those same living beings who create and perpetuate the ideal conditions of their own existence and what is needed for life to thrive, namely the atmosphere, the oceans, and the crust—geology and biology being coextensive to one another. Strongly affected by processes in the atmosphere, lithosphere, hydrosphere, and biosphere, the exchange of matter and energy that occurs within the CZ interacts with the other envelopes of the Earth System and determines the general habitability of the planet.

The CZ is perhaps the most heterogeneous portion of the Earth: it is where many physical, chemical, and biological components meet through complex linkages and feedbacks. It is a dynamic interface that makes the planet habitable: for example, by reacting with the rocks, the CO₂ from the air is neutralized on the continents to become limestone in the ocean. The CZ is all the more dynamic since it is the site of processes in which the involved elements are in constant transformation with each other through their interactions. The CZ is originally a very small portion of the Earth's surface where the activity of micro-organisms has developed and has gradually, over billions of years, generated the atmospheric composition,

transformed the rocks, etc. The boundaries of the CZ are therefore not fixed but in motion. It results that the CZ plays a key role in the dynamics of the Earth System and its major biogeochemical cycles, and for its feedback on its global regulation. As a support for life, this sensitive layer is strongly reactive to humans (agriculture, industrialization, urbanization, etc.) who shape the landscape, extract its resources, and store their waste. It is critical in the physical sense of the term because it is one of the limit interfaces of the planet, a threshold that can cause abrupt changes. But it is also critical in the political sense of the term as it has become the “zone to defend.”

Probably one of the most important applied aspects is the development of reliable data that will enable practices to protect the CZ. But, because of the coupled biogeochemical processes happening across spatial scales (from atomic to planetary) and temporal scales (from seconds to eons), the concept of CZ raises serious epistemological issues. As the geochemist Jérôme Gaillardet explains, there is a tension between lab experiments and field observations: when we try to reproduce how minerals in rocks are transformed into soil materials, we observe that the transformation rates obtained in the laboratory are much quicker (Latour & Weibel, [2020](#), p. 124). The reason for this difference is that all the factors that play a role *in situ*, such as the circulation of water or the composition of the soil, cannot be reproduced entirely in the laboratory. It is thus necessary to study each individual site in its entirety instead of studying one isolated reaction. This irreconcilable gap between the field and the laboratory challenges the scientific method—based on the assumption that it is the same everywhere and therefore can be reproduced experimentally—and paves the way for a science of the singular.

Drawing from Banwart et al. ([2013](#), p. 20), the big science question raised by the CZ could be summarized as follows: how can complex variable processes be quantified by empirical observation, measured by sensitive instruments, aggregated into data sets, and predicted by mathematical modelling? Research communities argue that the study of the CZ depends on strategies to cross disciplinary boundaries (Brantley et al., [2007](#)). For example, by combining the expertise of a geologist and a biologist, we can examine how one bacterium in the soil reacts to the presence of a metal. The concept of CZ thus challenges a conception of knowledge as object-centered and discipline-bounded, the study of a particular given object providing a particular discipline with its identity (matter for physics, life for biology, soil for geology, etc.). Process-oriented, the CZ involves entities which used to be studied by separate disciplines. The specialization of modern sciences is seen as a hindrance to an integrative—even holistic—scientific approach to the Earth that would facilitate the understanding of its behaviour in the face of great changes.

Processes in the CZ span wide spatiotemporal scales. If it takes a few seconds for a bacterium to reproduce in the soil, the degradation of minerals can take millions of years. If methane reflects atomic biochemical processes, it also involves global climatic factors such as precipitation. Interactions within the CZ thus require both long and frequent observations in selected ecosystems and at diverse locations. Numerous interdisciplinary programs called Critical Zone Observatories (CZO) have been created, particularly in the USA, Europe, and Asia (Anderson et al., [2008](#); Giardino & Houser, [2015](#); Brantley et al., [2017](#); Gaillardet et al., [2018](#)). Resulting in large amounts of data being collected across the entire planet by a wide range of disciplines, CZOs raise the question of the part-whole, both in terms of the relation of the parts to the whole and the relations between the parts themselves. How do the site-specific processes studied in the CZOs interact with the CZ wider system? Is the CZ more than its isolated parts and has properties of its own? Are the CZOs independent of each other and indifferent to their collection in the CZ? Are the global processes in the CZ just another

local variable, making the CZ at once what encompasses all the parts and a part next to the parts? This problem is evident in the hesitation as to whether the term CZ should be employed in the singular, designating the entire Earth's surface, or in the plural, with reference to specific locations.

As a science for the Anthropocene, the CZ has gone beyond the strict framework of the natural sciences. For example, the exhibition organized by the artist Peter Weibel and the philosopher Bruno Latour addresses this concept from aesthetic, philosophical, and anthropological perspectives (2020). The CZ eludes traditional visualizing tools such as cartographies because of the complex interactions happening between various entities, processes, and scales. In collaboration with the historian of science and stage director Frédérique Aït-Touati, the Architect Alexandra Arènes has multiplied initiatives to offer new conceptual depictions that allow scientists to represent the Earth by including the dynamism of geochemical cycles and living things that shape the CZ while considering the human as fully immersed within it (Arènes, 2017; Arènes et al., 2018; Aït-Touati et al., 2019). She notably uses anamorphic projections of the planet as seen from the inside rather than from outer space.

Latour has put forward the CZ as a scientific concept that is highly geopolitical, in the literal sense of a politics of the Earth (2014). The CZ forces us to change at once our understandings of what is a land and what is a people, transforming our definitions of both territory and sovereignty. Within the coordinates of the CZ, a piece of land is composed by multiple forms of human behaviours (from EU legislation to agricultural practices to consumers habits) as well as by a diversity of non-human actors (from organisms to rocks to gases). The challenge is to reconcile the connection between land and people without falling into the reactionary trap of current rising nationalisms. Latour thus coins the notion of the terrestrial to designate the earthly politics of life forms to be undertaken in the CZ for the age of the Anthropocene (Latour, 2015, 2017; Latour & Weibel, 2020).

As a thin layer, the CZ is neither the Earth nor the Globe. As the seat of life, the CZ might seem close to the concepts of biosphere and ecosystem. But its focus on geochemical processes moves us away from both biocentric and ecocentric approaches.

The postcolonial historian Dipesh Chakrabarty has both extended and questioned the geocentrism of the CZ (2019). He advocates instead for the concept of the planet which must be distinguished from that of Gaïa (centered around that which makes life possible) and from that of world (centered around the ground for human dwelling). For him, these two concepts are not geocentric enough because they do not consider the long-term planetary processes that out-scale both the temporal horizons of life and the human. In addition to the Earth's surface, the concept of the planet integrates: (a) the deeper parts of the underneath Earth that include the rocky, hot, molten interior and function independently of the CZ; (b) the planetary pluralism that requires comparing the Earth with other planets like Mars and Venus in order to understand the conditions for the planet to become the seat of habitability processes in the first place. The planet thus requires a theory of politics that forces humans to face a dimension of their action that exceeds their own existence on Earth.

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