Fear might be the best way to begin this section. This is at least the suggestion of Dipesh Chakrabarty in his interview: “I grew up in a place where fear was very much still a part of my life. Something about that reverence has to be brought back to supplement our very Aristotelian sense of wonderment ...”

Chakrabarty has been one of the first to convince historians — meaning historians of human adventures — to pay attention to the disorientation induced by the introduction of coal and gas into the rhythm of social and world history. Everything happens as if the global — what modernity was supposed to deliver on the surface of the planet — is entering into conflict with what Chakrabarty calls the “planetary” — that is, the same planet once dreamed of, except now it appears concrete, material, reacting to human actions, and above all, limiting global development.

Everybody nowadays is aware of the name geologists have given to this disorientation: the Anthropocene. Nobody has done more to make the discipline of stratigraphy known to the general public than Jan Zalasiewicz. This is the study group that he has assembled and guided has provided a scale for measuring the magnitude of human intervention into geological history that had not been realized before. And, indeed, “in the Anthropocene, almost everything becomes geology” (Jan Zalasiewicz).

Hence the sad beauty of Zalasiewicz’s summary of this human intervention, a picture achieved by reducing some of the geological data to a one-meter measure. How odd to realize that the biomass, according to this metric, is just five kilos per square meter, whereas the stuff humans have been able to produce — rubble, ruins, soil and all — weighs as much as fifty kilos! We knew “man was the measure of all things,” but we did not know the surprising length of that measuring stick. And to learn that the collective pressure of human activity is comparable only to asteroids at the end of Cretaceous or giant volcanoes at the end of the Permian, does not make the measure any less distressing.

After all, volcanoes too have been dragged into our culture, as Karen Holmberg argues, but it’s not reassuring that humans have become volcanoes themselves, especially as their kind of industrial eruption works 24 hours a day, 365 days a year.

No wonder that the word Anthropocene has metastasized to the point that Clémence Halle and Anne-Sophie Milton can refer to “the infinity of the Anthropocene.” The news is so disorienting that every discipline, every interest group offers an alternative term, insisting on this or that other variable, in order to cope with the maelstrom. That’s actually the good thing about this new geological label: it has spread everywhere and yet it is impossible to settle quietly in the historical period it designates.

It is actually one of the characteristics of the present that this disorientation can be observed in many different sites and at very different scales — which is what the layout for this volume allows. Witness the care with which an artist like Sonia Levy follows the work of oceanographers and biologists as they accompany and maybe preserve (or at least learn as many lessons as possible) from the threatened corals gathered in the basement of a Museum in London. It is every component of the former nature that has to be taken care of.

The same puzzle has moved Robert Boschman to explore the archeology of our only real predecessors, those hunter-gatherers living 12,000 years ago, who within only a few generations had to adjust to massive climate change. The Young Dryas episodes narrated by Boschman offer a meditation on how to cope with a massive disorientation in the order of the universe. Except our European ancestors might have been nimble in shifting their ways of life than we modern humans are; prisoners of our mammoth technosphere.

To order the universe is precisely what becomes difficult in a time such as ours. According to John Trehuc, “cosmograms” are objects, stories, images, and narratives that capture the spirit of a time or a new situation for which there is no received name. Just what we need when the whole machinery of time is getting out of joint. Cosmograms order the world just at the moment when there is no order. “What do they do — how do they propose, institute, challenge, satirize, critique, prop up, or quietly reinforce an order of the universe?” When Trehuc quotes Elisee Reclus’s “Humanity is nature becoming aware of itself,” we take stock of the distance between the optimism of geography in the nineteenth century and this more recent slogan of the activists in France today: “We’re not defending nature, we are nature defending itself.” Human consciousness is what seems to be in short supply today.

In times of uncertainty the crucial question is to decide whether we are able to tell the right story, and this time not to build a world of fiction but to have an imagination realistic enough to follow what the real world is made of and how; that is, what’s the story the world itself tells. A problem that Richard Powers, the great American novelist, has done more than anyone else to solve practically, by writing stories as they are: “And like it or not, the man and his measurements and the mountain and the neighbors and the forest and all that story’s readers are all a part of it.”
The Terra Incognita under Our Feet

Despite the importance of the Critical Zone for humanity, major questions are still unanswered. First of all, the Critical Zone is a "terra incognita" whose architecture is poorly understood. Beyond the conventional layered textbook representations defining the soil, the regolith, the ecosystem, the water table, the river, and so on, we lack conceptual representations showing the interconnections between these compartments which the different disciplines have erected and frozen as objects of study. Numerical models that tend to reproduce and predict the behavior of the Critical Zone are hampered by this lack of knowledge of its boundaries, and of the spatial and temporal connections of the object that sustains human activities and feeds us.

Very simple questions arise: What is the depth of the Critical Zone? What is its upper limit? What is lower limit? What are the processes that underlie the formation of agricultural land? What are the soil processes that sustain the life cycles of organisms? We know that the Critical Zone is a place where life, as we know it, exists, sustained by the sun, the atmosphere, and the water cycle. But what is the relationship between these processes and the life cycles of organisms? What is the role of the Critical Zone in sustaining life cycles? These are the questions that the Critical Zone Challenge seeks to address.

Critical Zone Observatory

To meet these challenges, scientists are getting organized. Following the initiative of the United States of America, Critical Zone Observatories (CZO), or networks of Critical Zone Observatories (CZONet), have been set up in various countries. A global network is being developed. These observatories are well-chosen sites, locations that are heavily instrumented and monitored over sufficiently long periods of time so that processes and fluxes in the Critical Zone can be identified, described, and incorporated into numerical models. Only observation over long time periods makes it possible to capture the dynamic nature of ecosystems — the tempo and rate of events — and the changing state of the Critical Zone, of extreme events as well as slow trends. CZO are agrosystems, cultivated or relatively preserved forests, cities, high mountains catchments, instrumented wells, or glaciers. The measurements made in CZO, either in situ (in the field) or on samples analyzed in the laboratory, are adapted to the processes that are locally best expressed. The instruments are often very sophisticated, whether they are installed directly in the field or in the research laboratories attached to those CZO. For example, the use of isotopic ratios to track the route of chemical elements in the Critical Zone and the processes in which they are involved (climate, precipitation, evaporation, uptake of nutrients by roots, etc.), or the deployment of passive or induced geophysical methods, such as the seismic imaging of gneiss transported at the bottom of streams, are widely used by Critical Zone scientists.

Each CZO is a place, a plot, a hilltop, a catchment, characterized by a unique, simply formulated scientific question, which is often of societal interest and for which the place has been chosen as representative. There is a Critical Zone, perceived as a new scientific object, but there are Critical Zone Observatories, all different in their combination of different parameters: geology, climate, topography, soil, living organisms, human activities, its history, or the conflicts of land use.

For example, a CZO can be designated to understand the response of the Critical Zone to the increasing (or decreasing) acidity of rain, the generation of destructive flood events, the response time of an agrosystem to changes in agricultural practices, the retreat of a glacier, or the role of climate change in Amazon floods. The main characteristic of a CZO is that it is site-specific; that is, determined by local conditions, and chosen to exemplify a particular type of mechanism to be understood in a particular scale. Elementary processes are discernible at the scale of a small river basin. At the scale of a region, such as the drainage area of the entire Amazon River, other processes emerge that require observations and modeling tools different from those required at the scale of a small river or a parcel of land.

In CZO or networks of CZO, ideally scientists from different backgrounds and speaking different languages work together to understand the object in an integrated way. They do it by sharing instruments, data, and numerical models. The beauty of this integration has allowed some CZO to attract scientists from the human and social sciences, while some are working more and more with local stakeholders, users, and citizens. One of the hopes of the global network of CZO is to develop a set of common metrics that can be applied everywhere according to the scale of observation to build standardized and interoperable common databases informed by common metadata. These data will describe characteristic processes at each scale, and will inform numerical models that will improve our ability to predict the evolution of the Critical Zone in response to climatic, anthropogenic, or geologic forcing.

Thus, to study the Critical Zone, scientists study critical places, as Alexander von Humboldt had already understood when he wrote in his famous book Cosmos (1845–50) that "everywhere, in every separate portion of the earth, nature is indeed only a reflex of the whole." Every corner of the globe, every CZO, is an instrumented natural laboratory, in which the processes and phenomena characteristic of the Critical Zone are identified.

The conceptual view that describes CZO not as static objects structured into different subsystems, but as animated by biogeochemical cycles is particularly new and relevant: CZO manifest the water cycle, the carbon cycle, the phosphorus cycle, or the cycle of rare earth elements, and are offering a new perspective on habitats. In the same way that the CZO provides information to paint the picture of the Critical Zone, each chemical element or molecule provides its own systemic image of the Critical Zone without caring about the divisions between sub-compartments. In this biogeochemical approach, the biogeochemical nature of the organism is less central than the chemical or physical reactions that they render possible. There is a significant difference here between the concepts of a Critical Zone introduced by Earth scientists and thus of ecosystem, introduced by ecologists — at least in the historical meaning of the term "ecosystem." Living organisms participate in the formation and evolution of a biogeochemical system that we must learn to name and represent better. Their biodegradation is important because it conditions the physical, chemical, and biological reactions in the Critical Zone (see fig. 7 and 8).

Our Territories Are "Critical Zones"

The concept of a Critical Zone does not set up an opposition between humans and nature or between living and non-living states. It refers to a system, which we still have difficulty naming and representing that is anchored locally, and orchestrated by biogeochemical cycles in which living organisms including humans are agents, among others. The sun’s energy animates these cycles, but they would not exist without the action...
Life in a Bubble: The Failure of Biosphere 2 as a Total System

Bettina Korinthenberg

A MAN-MADE Garden of Eden, Noah’s Ark for Mars — so the headlines ran in 1991, with the inauguration of Biosphere 2. The project undertook to reconstitute, on a smaller scale, the Earth’s own biosphere as a closed, total system. The media reports’ metaphorical overtones give an indication of the social context of the 1980s within which this extraordinary experiment began taking shape. At its core lies a relationship among three distinct aspects: on the one hand, there was the utopian dream of space colonization and, meanwhile, on the other, a nascent yet growing awareness of the planet’s limits in terms of overpopulation and environmental problems. Third, in the image of the man-made Garden of Eden, the human being as governing power and creator of an ideal realm comes into play. This idea also is found in the predominant concept in that decade of cybernetics as the science of governance of closed systems.

The engineer, systems ecologist, and author John P. Allen, along with businessmam Terry Bass, who was engaged in the environmental protection movement, wanted to turn utopia into a reality by duplicating the biosphere. Between 1987 and 1991, a gigantic glass-and-steel facility was constructed in the Arizona desert. The structure’s design, made of domes and pyramids, evoked a sort of sacred architecture of the future. Seven biomes — savanna, ocean, tropical rainforest, mangrove swamp, desert, an intensively farmed agricultural area, and living space for 18 people — were meant to represent Earth’s biosphere and therefore supposed to function as a completely closed and self-contained ecosystem. The goal of the venture was to begin a better understanding of the functioning of the biosphere, to develop technologies to aid in environmental problems such as air pollution, and to acquire foundational knowledge for future space colonies. For this reason, the project was monitored by NASA.

In September 1991, eight Biospherians dressed in overalls as if about to embark on a space expedition were sealed inside Biosphere 2. The experiment was planned to last for many years, but after only a short time, the system began reacting differently than had been expected and the crew left Biosphere 2 after two years on September 26, 1993. The space quickly became life-threatening for the humans and many of the life forms introduced into it. This result occurred despite the almost unlimited energy and technological resources that were available and the enormous efforts made by the Biospherians to keep the ecosystem running. Oxygen levels dropped so low that oxygen had to be artificially introduced from outside. The majority of insects died and pollinators survived, leading to the proliferation of ants, roaches, and crickets. The human inhabitants suffered from malnutrition. It was impossible to sustain life inside this biosphere created by humans. Biosphere 2 therefore became, not long after its inauguration, a focus of hard scientific and media controversy.

James Lovelock’s description of Gaia — a concept he coined with Lynn Margulis to name Earth’s ever-changing biosphion, produced and maintained by the activities of all its life forms — is central to understanding the failure of Biosphere 2. “[Gaia] is an evolving system, a system made up from all living things and their surface environment, the oceans, the atmosphere, and crustal rocks, the two pillars tightly coupled and indivisible. It is an ‘emergent domain’ — a system that has emerged from the reciprocal evolution of organisms and their environment over the eons of life on Earth. Self-regulation emerges as the system evolves. No foresight, planning or technology are involved. According to Vladimir Vernadsky, the biosphere may be defined as a space in which all life is materially integrated — an explanation that comes close to the understanding of Gaia. The biosphere has an open, processually self-evolving, emergent system that cannot be calculated in advance, nor assembled from component parts or adjusted to scale. Biosphere 2 was itself too small to generate its own changes in weather or movement in its ‘useless’; nor was it able to regulate changes in temperature and chemical composition across vast water and land surfaces. And it wasn’t just the scaling that proved problematic, but also the selection of animal, plant, and geological inhabitants. The respective experts in charge of each biome assembled the selection of life forms that would be settled into the quasi miniature versions of, for instance, savanna or rain forest. In so doing, they tended to focus on animals and plants that had a presumed utility for human beings. Accordingly, the selection was in fact centered on human life and its survival. This selective extraction of biotic and abiotic components and their calculated assembly will never be able to adequately reconstruct or simulate the temporal dimension of the biosphere’s development as an open system which has been evolving over millions of years. The problem with this centering of the human being was most remarkably evident in the increase of CO₂ in the space and, in this case in particular, in the context of the life forms that inhabited its soil. The soils of biosphere 2 were heavily enriched with nutrient-rich compost and dung, as the planners wanted to take advantage of the opportunity to provide the inhabitants with as many nutrients as possible to supply them. But the high number of bacteria and mushrooms that thrived in this enriched soil caused CO₂ levels to rise sharply, as a result of their own metabolic and respiratory processes. The failure of the Biosphere 2 experiment demonstrates the error in the idea that human beings could serve as engineers of the Earth system, composing a whole from parts — an error that risks the extinction of the human species and the life forms that exist along with it. In the context of acute environmental crises and their consequences for life on Earth, this failure implies our chance to gain awareness of the Earth’s uniqueness as a living environment, with its fragility and inescapability, and to develop a different attitude toward and new modes of engagement with all forms of territorial life.
vegetation flourishes throughout the whole terrain, all the way up to the snowline. The Himalayas, Humboldt eventually conceded, were taller than the Andes, but their higher latitude caused vegetation to cease at a lower altitude. A view from their highest summits reveals mainly rocks, ice, and snow: “nearly a solitary palm-tree to be found in the beautiful valleys of Kumaon and Gwalwal” ([166]).

The range of plant life observable in the Andes mirrors the Naturgeschichte’s synthesis of isolated impressions into a whole. The role that climate plays in the natural synthesis is the role knowledge plays in the painted one. Plants must be identified by species, and their distribution must be mapped “physiognomically,” as outward symptoms of underlying processes. The purpose of the Naturgeschichte, however, is aesthetic. The “view of Nature” (Naturansichten) consists in “the removal of superficial forms, to afford to sensitive minds.” Humboldt wrote his books both to instruct and to entertain. Their entertainment value transcended the task of reaching a general audience. Beyond the purpose of illustrating education lay the epistemic power of die Bild [the picture] itself. For, if in nature everything was interwoven with everything else, then the representation of nature to humans must be interwoven with humans. The aesthetic character of nature painting is not ornamental (as illustration) or rhetorical (as mode of persuasion) but conforms to Humboldt’s insight that nature, which encompasses the human, must be communicated to humans according to their sentient nature, which is to say aesthetically, in the original sense of ästhetischer [aesthetic] as “pertaining to sense perception.”

In the first volume of Cosmos, Humboldt’s “paints,” a portrait of nature, starting from outer space and descending down to Earth and into the soil, where fungi flourish and dermatids feed. Then, seemingly as a codex, he turns to the human species, concluding with a long citation from his brother Wilhelm’s writings on the “idea of humanity,” and how humans venture out of their own domain to the wider world only to return to themselves in the form of the study of their historical past. Accordingly, the second volume of Cosmos turns to past portrayals of the natural world, starting with the earliest landscape poetry and painting. Humboldt insisted that the Naturgeschichte belongs to a history of art and that this history therefore is a resource for future representations of Earth understood as (in our times) Critical Zone. Early on in that history, at the birth in Europe of the autonomous gallery picture — das Gemälde — Jan van Eyck produced landscapes more capacious than any natural view. (Reportedly, this painter also created a circular representation of the world: “you may distinguish in it not only the places and the life of the continents,” wrote an observer in 1450, “but also by measurement, the distance between places.”) These landscapes served as backdrop to religious scenes, but van Eyck and his followers also recognized that vast vistas might fascinate at least as much as would the sacred personages portrayed as if alive in front of them, hence the conceit of establishing in a middle ground tiny viewers, depicted with their back toward us, gazing into the beautiful distance. Eventually such vistas became the specialty of entire painting workshops, especially in Antwerp, northern Europe’s painting capital. In 1868, around the time that the term Weltschauung was gaining popular currency, academic art historians in Germany coined the term Weltanschauung to characterize this historical development. Developed by Joachim Patzer and Quniten Menten, such landscapes found their greatest expression in the art of Pieter Bruegel the Elder.

Bruegel’s worldscape are always nature-cultures (see fig. 2). On a ground plane rising steeply to a narrow strip of sky this artist lays out a vast terrain stretching from watery flats and floodlands reminiscent of his native Flanders to the snowcapped Alps and beyond, and always with open ocean somewhere in view. This immensity he also defines as an arena for human activity — sometimes in the form of seasonal labor, sometimes as a variety of cultural practice: customs (e.g., carnival and Lent), play (children’s games), language (vernacular proverb), etc. Landscape dwarfs and naturalizes the human, integrating Bruegel’s players into the rhythms of day and season and submitting them to the challenges of survival. This encourages a stoic viewpoint. One can gaze upon a static antiquity at the absurd undertakings of the human animal. Bruegel’s visual humanism poises the world as humankind made, not naturally found, dependent, art historically, on a radically different Weltanschauung. Bruegel’s landscapes, as well as almost all of his subjects and themes, depend on the anti-human art of Hieronymus Bosch. Working two generations before Bruegel, Bosch fashioned cosmic panoramas observed from on high. Yet his paintings are haunted by another viewer who, always yet higher up, sees us before we see him. At first glance, the implied beholder appears to be an art-loving, privileged, and (perhaps) pious patron who takes strange pleasure in torments and catastrophes occurring to others, especially the poor and marginal: violent death, erotic torture, deluge, devilish domination, conquest by enemies, apocalyptic, and so forth. On the other hand, the true and sovereign beholder is God, who sits in judgment above and sees us before we see him. The human — both in the painting and before

7 Humboldt, Cosmos, vol. 1, 38.
10 Erikhard Freiherr von Bohdenhausen, Gerold David und seine Schule (Munich: Bruckmann, 1985), 208.