THEORY OF THE EARTH

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Contents

Illustrations

Introduction

WE NEED A NEW THEORY OF THE EARTH. Most people are accustomed to treating the earth as a relatively stable place that they live on and move on. Today, however, this stable ground is becoming increasingly unstable—for some of us more than others.[1]

Due to the widespread use of global transportation technologies, for example, there are now more people and things on the move than ever before in history. Vast amounts of materials are in constant circulation as billions of humans ship plants, animals, and technologies around the world. More than half the world's plant and animal species have now been forced into migration due to climate change.[2] The earth is becoming so mobile that even its glaciers are speeding up. Karl Marx was not thinking of receding glaciers or greenhouse gases when he said "all that is solid melts into air," but that is what is happening.

Geological time used to refer to slow, gradual processes, but today we are watching the land sink into the sea and forests transform into deserts in our lifetimes. We can even see the creation of entirely new geological strata made of plastic, chicken bones, and other waste that could remain in the fossil record and affect geological formations for thousands, even millions, of years to come.[3]

Some human groups are now changing the entire earth so dramatically and permanently that geologists have begun calling our age the Anthropocene.[4] It no longer makes sense to think of humans as transient occupants moving on a relatively stable earth. Humans are geological, atmospheric, and hydrological agents entangled in all the earth's processes, which are now increasingly in flux. The arrival of the Anthropocene, more than any human

historical event, is finally awakening us to the realization that we have never lived on a stable earth. There is significant literature now on climate change and the role of humans as geological agents.[5] Nevertheless, I argue that the most radical import of the Anthropocene is the unpredictable agency and mobility of the earth itself.

In other words, defining the Anthropocene by human historical markers such as agriculture, the industrial revolution, and nuclear bombs should not cause us to lose sight of the most important lesson of our time. *Nature and humans have never been separate systems.* The Anthropocene is not only about humans and what they have done to the earth. It is about the earth and what it is doing to itself through humans.

However, the participation of the earth in climate change in no way negates the need for ethical action on the part of humans.[6] Climate change is a significant problem that demands radical social change. Some historical actors and social systems are particularly responsible for ecological destruction, while others are disproportionally affected by its consequences.[7] But these problems will not be solved using our old paradigm of humans *as separate from* nature. New epochal problems require new philosophical and historical orientations, which is why this book tries to provide a new theory and ethics of the earth for the present.

We tend to think of the world in terms of stasis rather than process. In our zeal to halt our runaway energy consumption, we act as if the goal were to conserve, accumulate, and stabilize energy use. And yet humans, as part of nature, have evolved alongside other life forms in a way that maximizes our collective energy use, flow, and movement.

But it has gotten to the point now that we won't even let our trash degrade. We make things from plastics that last for tens of thousands of years and then bury them underground. Vast islands of plastic are floating in our oceans like quasi-immortal beasts. The net effect of all this is that the planet's *own* energy consumption is *slowing down*, with disastrous consequences.

We continue to think of the earth in terms of stability and conservation, against our best interests. This book is motivated by the advent of increasing planetary mobility, which pushes us to think about the earth and its history in a whole new way. We need a different history and ethics that will help us to go *with* the flow of planetary energy processes, not *against* them.

TWO PROBLEMS

The Scottish "father of modern geology," James Hutton (1726–1797), published his groundbreaking work, *Theory of the Earth*, more than two hundred and thirty years ago, in 1788. Hutton wrote at a time when humans knew little about geological processes or the age of the earth. The 18th century was a time when geology was still a wide-open field.

Like all new sciences, geology was mostly theoretical at first. Over time, it was separated from philosophy and made into a physical science. As more time passed, other sciences, such as chemistry, physics, biology, and cosmology, had philosophy turn its attention back to them, but geology has still not become a subject of philosophy again.[8] To my knowledge, there is no definitive book-length work on the philosophy of geology in existence today.[9] However, given our present historical situation, I think it is high time for philosophy to rethink the history of the earth.

I wrote this book because I think there are at least two significant problems with our theories and treatments of the earth in the Western tradition.[10] These problems are at the heart of the current ecological crisis, and whether or not we overcome them will play a significant role in the survival of future planetary forms of life.

Stasis

The first problem is that of stasis. Historically, we have tended to view the earth as the stable object par excellence.[11] Many prehistoric mythologies described the earth as the primordial womb or egg from which all things were born and to which they cyclically return.[12] In the ancient Near East and the classical world, most people thought of the earth as the stable center of the universe, a static sphere upon which the whole cosmos turned.[13] For Copernicus, the earth itself was still a relatively unchanging sphere, even if it rotated around the sun. Even Hutton defined the earth as a profoundly slow, uniform, and relatively stable cycle of balanced change.[14]

The theory of plate tectonics, in the 1960s, was the first major geological revolution to question the stability of the earth itself. However, even then, the near consensus of "uniformitarianism" still described tectonic movements as slow, uniform, and relatively homogeneous. Even when we have acknowledged that the earth moves, we have rarely and only recently begun to acknowledge that the movements of the earth are profoundly and unpredictably affected by, and integrated with, nonlinear and non-geological cosmic, biological, and chemical processes.[15]

We have treated and, in various ways, continue to treat the earth as a kind of unmoved mover.[16] We either act as if our scientific knowledge about the earth is a separate thing, unconditioned by the earth itself, or we think that the earth that

existed before us and will exist after us is somehow radically unrelated to us.[17] Most geologists still believe that there are uniform and mechanical laws of geology.[18] Most of us in the West are unconscious uniformitarians. We still act like the earth is largely stable but punctuated by exceptional environmental disasters.[19]

Meanwhile, we have new technologies, including high-precision geochronology and satellite observation, along with detailed data on the earth's temperature, precipitation, river flow, glacier behavior, groundwater reserves, sea level, and seismic activity. We can now directly see that many of the earth's processes are neither as slow nor as constant as we thought.[20] All of our significant predictions about climatic change failed to anticipate how rapid and nonuniform the changes have been so far and how integrated the earth's systems have proven to be.[21] Climate scientists still have no working models to explain sudden "tipping points" in the earth's history, where temperatures suddenly rise 10 to 15 degrees in less than ten years.[22]

Treating the earth as stable, uniformly predictable, linear, or mechanistic allows us to continue to act as if we can pollute it and extract as much as we want from it without significant or uncontrollable consequences. If the earth is just a bunch of mechanical stuff, we can treat it however we want and then mitigate the problems with geo-engineered solutions.[23] So far, however, no such technical fixes exist that are feasible, nor are any likely to appear.[24] As George Bataille once remarked, "All that we recognize as truth is necessarily linked to the error represented by the 'stationary earth.'"[25]

History

The second, related problem is that we have treated the earth as an ahistorical substance lacking genuine novelty.[26] For most of recorded Western history, humans have thought of the earth primarily as a passive object or as the product of natural, divine, or mechanical laws. The natural sciences frequently explain the movements of the earth according to causes other than the earth itself (laws, forces, principles of uniformity, etc.). Geological histories are thus typically histories written about the earth, not histories written as practices of the earth itself.

The anthropocentric assumption is that only when nature becomes aware of itself in the human being can we say that it becomes genuinely historical and meaningful.[27] Western historians have long believed that only humans can have a history, because only humans are self-conscious and genuinely novel agents.[28] People too often think that the earth's systems simply form the backdrop or stage upon which real history, i.e. human history, occurs.[29]

This anthropocentric narrative is evident from the almost complete historical erasure of earth processes as active contributors to some of the most significant events in Western history. The Holocene glacial retreat, the medieval warm period, and the "little ice age" all played significant active roles in shaping human history. Yet historians frequently leave these events out of the books.[30] Earth processes like volcanoes, fires, hurricanes, earthquakes, and tsunamis also continue to shape history in crucial and active ways.[31]

Even when we acknowledge the activity of the earth, we tend to do so while thinking of the earth as a living and vital subject like ourselves.[32] Unfortunately, this is still a biocentric image of the earth. This image misunderstands inorganic matter as being like organic matter when the historical situation is precisely the

opposite. The earth is mostly *not* alive. The earth is part of much larger non-living cosmic cycles and patterns that are not fully captured with the idea of the planet as an organic individual (Gaia).[33] The earth is neither in stasis nor in homeostasis; it is neither mechanistic nor vitalistic; it is neither an object nor a subject. Instead, I argue, it is a turbulent process operating far from equilibrium.[34]

I do not think, as some do, that we have arrived at the "end of nature," in which nothing exists unmixed with human activity.[35] The origins of this idea were well-intentioned but wrong and are now potentially dangerous. The idea was that if we emphasized how significant and widespread human intervention in nature was, that would help us see that nature is a human ethical issue we should take seriously.[36] However, the flawed assumption of this position is that reality can be otherwise than it is only through human activity.

Unfortunately, the focus on human structures[37] and human-nature hybrids[38] has tended to obscure the profoundly nonhuman indeterminacy of the earth and the cosmos.[39] Not everything is or has been a human hybrid. Human-nature hybrids are only a very tiny portion of nature.

There is today a marked reluctance (whether implicit or explicit) on the part of humanists and social scientists to interrogate the prehuman material conditions of human beings.[40] Critical and social theories always seem to begin and end with human histories rather than with the deep historical prehuman earth as the turbulent and mobile condition that is immanent to humans themselves.[41]

On the one hand, I think that the geosciences need to recognize the historical and social conditions of their claims about the earth. On the other hand, the social sciences and humanities, in turn, need to recognize the geological conditions of their concepts and

social structures.[42] Moreover, both need an immanent critique of the earth as their shared material kinetic condition.[43] For all the recent interest in things and objects in the theoretical humanities, there has been ironically little attention given to the earth.[44]

The danger of starting all our histories with classical Greece or early human evolution is that it gives us an inflated sense of our importance. For example, if humans do not take the earth's deep and turbulent history seriously, we are more likely to think that we can dominate or geo-construct it at will.[45] If we want to overcome the nature-culture duality, we need to start taking the cultural history of the earth seriously.[46] Starting our histories with European modernity or even human history only reasserts an implicit division between nature and humans, whatever we might say to the contrary.

I worry that if we think the earth has no genuine historical agency, we may foolishly think that it can have no real effect on human history. Natural scientists often treat earth systems as passive mechanical processes following universal laws, punctuated by random changes. However, we ignore the truly indeterminate movement of the earth at our peril. The deep history of the earth is not a secondary or derivative history merely told by humans about something that they are not. The earth is the immanent material condition of human historicity itself.[47] Humans are the earth and therefore bear its history. In my view, our ability to see this ought to be the real point of the Anthropocene.

The aim and novelty of my work here in *Theory of the Earth* is to overcome these two problems, the problems of stasis and of history, by inverting their static and ahistorical assumptions. What new philosophy and geology might await us if only we took seriously the earth's genuinely unpredictable power of movement? What would it mean to reconsider human ethics and politics as terrestrial and geological formations?

A HISTORICAL ONTOLOGY OF THE EARTH

The Anthropocene marks a new period in geological history. It forms the limits of a previous epoch and provides the outline of a new one, defined in part by the increasing mobility and instability of the earth.[48] However, the advent of the present is never limited to the present alone. Now that our present has emerged, it is possible, in a way that it was not before, to inquire into the conditions of its emergence and discover something new about the nature and history of the earth's constitutive mobility.[49]

Most of our existing theories assume that the earth is homeostatic, uniform, stable, or capable of being stabilized by life. However, it seems to me that the recent increase in planetary mobility, sudden climatic change, and emergent feedback patterns in earth systems ought to draw our attention to this instability.[50] More importantly, it should draw our attention to a previously hidden dimension of the earth's fundamental instability, only now coming into view: the earth is suddenly proving to be more mobile and eccentric than we thought possible. It's time to start taking this seriously. It's time for, among other things, a different conceptual framework.

The approach of this book is not to write a philosophy *about* the earth, as a distinct substance separate from philosophical practice or humans. Humans and their philosophies are not outside of or separate from the earth's systems. *Theory of the Earth* is also not a "natural philosophy," "cultural history," or "geophilosophy" that studies human thoughts about nature or the earth's relationship to human thought or culture.[51] The focus of this book is instead on the earth *itself as a theoretical practice*.[52] Recent works have done a good job of showing the importance to humans of geological and material processes. *Theory of the Earth* goes one step farther, theorizing these deep geological and material processes themselves.

This book is also not a philosophy of geological science as a human institution.[53] *Theory of the Earth* makes extensive use of contemporary earth and natural sciences but does not critically engage them all using the full repertoire provided by science and technology studies. There are already plenty of books that do this, including my own.[54] My purpose and usage here are entirely different. I cite scientific studies in this book not because I naively accept them as universal truths about the objective facts of nature nor because of so-called science envy.

Instead, *Theory of the Earth* treats the earth sciences as real historical ontological dimensions of our present. Rather than trying to prove that knowledge and nature are endlessly open to human revision and reconstruction, my goal here is to demonstrate the performative reality that the earth itself has produced *as* our scientific knowledge of it. Knowledge is not something we have *about* the earth, as if the earth were something separate from us. Knowledge is something that a region of the earth performatively *does* to itself and with itself.[55] This book is a study of the deep historical and material conditions of this earthly knowledge performance.

Before there were humans, the earth moved independently of what humans thought about it.[56] However, this deep historical earth and its cosmic flows are not radically unrelated to humans. The present is the key to the past because some of the past coexists immanently within the present, within us. We cannot go back and change the earth's deep history, but insofar as it is literally in our bones, we are immanently related to it.[57]

We are not cut off from access to the earth, nor stuck inside our heads. Our heads are not entirely our own—they too belong to the earth. We have access to the earth and the cosmos because we *are* them, albeit only a small region of them.[58] We can, therefore, know something about this deep history precisely because it is the

material condition of our very existence. Our bodies and cultures are material memories or traces of the deep history of the cosmos and the earth. This is the earth I am primarily interested in. By this, however, I do not mean that there is only one true objective earth that humans can know absolutely, or even progressively, through science. The earth is neither a single objective reality nor a mere construction of human scientific knowledge.

The methodology of this book is what I call "historical" or "material" ontology. It is historical and material in the sense that our practical inquiry always begins from somewhere historically particular: the present-day earth. From the specificity of the present,[59] the world *is* a specific way, a way that includes us as a region of that same world.[60] Sensation, knowledge, and the historical present are not separate from the world just because we are humans.

This method is ontological in the sense that our situated descriptions are real aspects or dimensions of reality. My method is neither about the earth in itself, independent of or unrelated to us (naive realism), nor about the earth as it is strictly for us (constructivism). There is no division; we are a region of the real earth itself. Its deep history persists into the present as our immanent deep history. The earth really and performatively constructs itself.

In other words, my question is not "what is the earth like in itself?" or "what is human language, mind, economics, or power like such that it is possible to think of the earth?" My question is, "what are the material and historical conditions of the earth, up to and including us?" Multiple human structures shape contemporary reality. These structures are, in turn, conditioned by other real, terrestrial processes that have been around since long before humans walked the earth.[61] This is what I am

interested in: the deep conditions of the present.[62] What is especially interesting is that these conditions have turned out to be more profoundly eccentric than we ever imagined.

This work aims to locate the historical conditions of this present-day eccentric mobility.[63] It is not a universal history but a single situated account, among others, from the vantage of the present. I do not offer any final word or universal theory of the earth.[64] Reality does not mean totality. Human history is open because the movement of the earth is open, not the other way around.

The history of the earth is like a double image. In the well-known images of the old/young woman and the duck/rabbit, both figures are really there in each case. Both descriptions are true and different at the same time. The earth, however, is not just two images but a vast multiplicity of images, and the perceiver of those images is only a region of the image itself that actively changes the image by looking at it.[65]

The natural and earth sciences tend to act as if there were one fixed objective world and a single set of universal natural laws about that one nature.[66] However, there are as many natures as there are paths leading from past to present. All the paths are real, just as each figure in the double images is real. If humans are part of the earth, then so is this book. What are the cosmic and terrestrial conditions for this book and for the body writing it?

Theory of the Earth is both a theory of the earth before humans and, at the same time, a theory of the immanent material conditions of the human itself as a region of the earth's deep history.[67] They are the same ongoing history. The historical ontology of the earth is thus not situated because we are humans but, rather, we are humans because we are a historically situated region of the earth's present.

Theory of the Earth is, therefore, not a theory in the traditional sense of an abstract and universal mental representation of the world. Instead, it is a "theory" in the etymological sense of the Greek word *theōría*, as a "movement, sending, or process." Theory is, therefore, a performative process that describes the structure of the immanent movements that constitute it.[68]

MOVING TOWARD A KINETIC THEORY OF THE EARTH

Theory of the Earth reconsiders the immanent history of the earth from the perspective of the increasingly unstable mobility that defines the Anthropocene. It thus provides a uniquely movement-oriented or "kinetic" theory of the earth. This methodology has two significant consequences.

First, by focusing on the movement of the earth, we are able to avoid problematic theories of the earth as an "active," "generative," "vital," "living," subject or as a "passive," "law-driven," "mechanical," "dead" object. I find it unhelpful to divide, oppose, and choose one side of these binaries against the other.

Matter in motion is the immanent historical condition for both subjective and objective dimensions of the earth. There are different patterns or regimes of motion, but movement has no historical opposite. There is, strictly speaking, nothing in the universe that is not in motion.[69] Even space and time themselves are products of motion—not the other way around.[70]

Motion is neither determined nor random. Patterns of nature are emergent features of a universe in motion. There are no laws of nature before there is a universe in which those laws are emergent features. In short, motion allows us to overcome the dualisms we have projected onto the earth.

Second, focusing on movement allows us to see the material continuity between beings that have historically been thought of as categorically and ontologically divided. Movement, for example,

flows between cosmos, planet, life, humans, animals, plants, rocks, microbes, and so on, down to the smallest vibrations of matter. The movement of matter plays a constitutive role at every level. Rather than project our own life and subjectivity back onto the earth (Gaia), this book begins its history prior to life and the earth to show how they emerged as a material process.

As mentioned previously, the assumptions of stasis and stability are at the core of the Western project.[71] They are at the top of the great chain of being. Our most straightforward definitions of motion, as a transition from point A to B, assume a static background and internally static, self-identical, points "A" and "B." Even when we consider closed cycles, loops, and orbits, we assume a change that merely oscillates between A and B without any fundamental instability in the line itself.[72]

The material basis for this abstract idea of a static background and identical points is the earth. One of the main reasons we have assumed planetary stability in the first place is because most of human history has taken place during a geological epoch of relative climatic stability, the Holocene. In other words, our idea of motion is historically and geologically particular—but we have taken it to be universal.[73] This is the great epochal error of our time.

However, if the earth is a non-uniform and turbulent mover, as I argue, then the movement from A to B is much more like a continual transformation of the whole line AB itself.[74] The earth is not uniform. Its movement is turbulent, unstable, and entangled with the cosmos in ways that we are only now discovering. This has radical and undertheorized consequences for our understanding of the earth and of motion.

A THEORY, HISTORY, AND ETHICS OF THE EARTH

I have organized this book into three major parts covering the theory, history, and ethics of the earth.

Part I: Geokinetics

I propose a new movement-oriented theoretical framework of the earth as an alternative to the traditional ones defined by stability. Instead of thinking about the earth as an object, subject, substance, or essence in isolation from the cosmos, I introduce a process theory of the earth. I call this a "geokinetic" theory because it treats the hydrosphere, lithosphere, atmosphere, and biosphere as fully integrated earth processes that flow, cycle, and circulate through one another.

The kinetic theory of the earth begins from the contemporary observation that the earth is much more fluid and unpredictable than we ever thought possible. The earth flows. We are now aware of the deep historical coproduction, or "sympoiesis," of all kinds of material flows that we used to study separately. Flows of rock, flows of water, flows of air, flows of life, and even vast cosmic flows of matter are profoundly interdependent processes. What if we retold the history of the earth from this perspective?

In my previous books, I began my historical ontologies with early human prehistory in order to study the longue durée of the emergence of politics, ontology, art, and science in the Near Eastern and Western traditions. In all of these works, I attempted to show the hidden and constitutive primacy of movement and matter. Although I started with human history, the goal was to show the transversal historical patterns of motion that moved through human and nonhuman processes alike.[75]

But where did these patterns of motion come from in the first place, if they were not the sole invention of human beings? *Theory of the Earth* is an answer to this question. What I call "geokinetics"

is the study of the deep historical and material conditions for the emergence of, among other things, human politics, ontology, art, and science. In my movement-centered philosophy, I named my study of these areas, "kinopolitics," "kinology," "kinesthetics," and "kinemetrics" to emphasize the primacy of movement. A central thesis of this book and of "geokinetics" is that humans and their culture are continuous with cosmic and terrestrial processes of kinetic dissipation (see Table I.1).[76]

Human culture is only a regional and specific expression of what nature has already been doing in a general sense for a very long time. I realize that this is a big claim, and I do not expect most readers to agree with it immediately. But if it is accurate, it has enormous consequences.

Part II: History of the earth

Another consequence of my movement-oriented perspective is that it makes possible a new history of the earth. Against mechanical and vitalistic theories, I argue that the history of the earth is about the indeterminate dissipation of energy through four patterns of motion.

TABLE I.1 Theory, form, content, and patterns of motion

THEORY	FORM	CONTENT	HISTORICAL PATTERNS
Kinopolitics	Relation	Border	territorial, political, juridical, economic
Kinology	Modality	Surface	space, eternity, force, time
Kinesthetics	Quality	Image	function, form, relation, difference
Kinemetrics	Quantity	Object	ordinal, cardinal, intensive, quantum
Geokinetics	Nature	Earth	mineral, atmospheric, vegetal, animal

Each of these patterns is associated with the rise and prevalence of a different planetary structure in the earth's history. Minerals emerged through a centripetal motion, the atmosphere through a centrifugal motion, plants through a tensional motion, and animals through an elastic motion. In each historical eon, a new regime rises to predominance, while all the older ones persist and mix with it. Now, in the 21st century, we find our contemporary earth at the intersection of all four major historical regimes. These are the limits not of what the earth can do, but rather of what the earth has done so far (see Table I.2).

The earth is not just a rock. In fact, a rock is not just a rock. The profound uncertainty of the earth's systems today prompts us to completely reconsider our previous categories, substances, teleologies, and hierarchies. We need new definitions and histories for these new hybrid processes of mingled minerals, atmospheres, plants, and animals. We need a process theory of the earth based on patterns, not substances.

The conditions of the present are not locatable in the present alone nor in human history alone. Deep history, in all its uneven flux, is the key to understanding our planetary present. The past does not go away but persists and coexists, to varying degrees, in the present. In other words, there are humans only because there are rocks.[77]

A new kinetic history of the earth will help us to see more fully the present earth that we *are* and how to live better on it. This history is critical if we are to move away from our current tendencies toward mechanism, vitalism, uniformitarianism, geo-constructivism, and homeo*stasis*. This book is an immanent critique of our moving earth.

TABLE I.2 Patterns of motion

	CENTRIPETAL	CENTRIFUGAL	TENSIONAL	ELASTIC
Politics	territorial	political	juridical	economic
Ontology	space	eternity	force	time
Art	function	form	relation	difference
Science	ordinal	cardinal	intensive	quantum
Nature	mineral	atmospheric	vegetal	animal

Part III: The Kinocene

The third consequence of the kinetic theory of the earth is that it will provide us with a new perspective on contemporary life—what I am calling the "Kinocene." There are as many Anthropocenes as there are ways to think about the present. That is a good thing.[78] So without wishing to negate the others, I would like to propose the addition of one more. The Kinocene is an age defined by the earth's post-Holocene return to itself as an increasingly mobile, turbulent, and dynamically entangled process.

This transition is historically gendered, raced, economic, and asymmetrical, and in our examination of this transition, we must also think about the real possibility of human extinction, something we want to avoid. But it is also crucial to recognize that the Kinocene would be nothing without the contributions of the earth itself. These include fossil fuels, metallurgic compounds, positive climate feedback processes, hydrologic conditions, and the plants and animals that also transform the climate.[79]

Of all the names for our geological epoch, we should not forget the earth itself as a constitutive part of this transition.[80] The twin narratives of humans as earth-destroyers and as earth-savers are

two parts of the same anthropocentric dilemma.[81]

By thinking only about our own movements of energy expenditure and conservation on a "relatively static earth," we have failed to see ourselves as part of the larger cosmic and terrestrial drama of increasing flow rate and mobility. By damaging the earth's dissipative processes (especially the biosphere), humans have slowed down the kinetic movement of energy throughout the planet. Fossil fuel capitalism has increased human energy consumption, but only at the cost of decreasing planetary energy consumption by much more.

I rewrite natural and human history from the broader perspective of movement. This offers a new ethical orientation to our "Kinocene" present and to the cosmos. My thesis is that, if humans want to survive, then the most geohistorically likely way forward is to contribute to the earth's massive process of energy expenditure, including land fertility, biodiversity, and climate stability. This shift requires us to reject our current biocentric emphasis on conservation in favor of expenditure and flux.

Today, unprecedented increases in the earth's unpredictable mobility prompt us to reconsider all our planetary paradigms. These changes challenge us to reconsider the nature of nature as well as the deep history of the earth. Perhaps most importantly, the earth's turbulent mobility forces us to rethink our ethical relationship to one another, the planet, and the cosmos at large. The Kinocene is calling us to become what we are: the earth.[82]

PART I

GEOKINETICS: THE KINETIC EARTH

1

The Flow of Matter

THE EARTH FLOWS because the matter of the cosmos flows through it. In this chapter, I take the flow of matter as the starting point for a new theory of the earth. This is because I think the earth is much more like a process than it is like a stable object (Spaceship Earth) or autonomous subject (Gaia).

The earth is a material process continuous with the expansion of the universe that produced, and continues to produce, the earth. The earth is not a vacuum-sealed object cut off from the outside. Nor is it an unchanging or uniformly changing substance following autonomous processes. Geology flows from cosmology.

Flows of matter continually compose, cycle through, and flow out of the earth. The earth is only the regional circulation of a much larger kinetic and entropic process. Historically speaking, philosophy, politics, and much of geology have not taken this ongoing flow of cosmic matter seriously.

This has led to an inverted understanding of the earth and our relationship to it. We have posited ourselves and the earth as profound reversals of the general movement of the universe, which flows, cycles, and dissipates entropically.[1] The crowning achievement of reversal is anthropocentrism.[2] We look at the universe and think how wasteful it is. Against its waste, we think life, and human life in particular, is so special because it fights against the waste of cosmic entropy. We have cast ourselves as the heroes in a universal drama of life against death.[3]

In this book, however, I offer a different perspective. The earth, I argue, is not so much a "planet" as it is a process of terrestrialization. It is the cosmos continually made earth. Every product presupposes a kinetic process, and this is where I propose to start with the earth. Part I of this book aims to rectify the missing theory of motion behind our thinking about the earth. It begins with the cosmos as the immanent material condition of the earth.

This accomplishes two significant moves. First, it abandons any notion of the earth as an absolute ground, of itself, of history, of humans, or thought. Geophilosophy and geoscience have both granted unjustified primacy and autonomy to the earth. This is why the instability of the Anthropocene has caught them so off guard. The earth is not behaving like the good ground it is supposed to be. The Anthropocene is less an age of humans than of the inhuman. And second, it provides a new conceptual vocabulary with which to talk about how indeterminate fluctuations of matter can produce and sustain emergent kinetic patterns continuous with the larger cosmos and with one another. If the matter that makes the earth is unstable, then so is the earth.

In Part I of this book I start with the idea that the earth is made of material flows. From there, I lay out a kinetic theory of the earth that I call "geokinetics." Geokinetics has three aspects: the flow of matter, the fold of elements, and the circulation of planetary fields. These are the three terms in my conceptual framework. I hope that they will position us well to put forward a process theory of the earth. This framework, although it may sound abstract in some places, will help us, in Part II, to reinterpret the deep history of the earth, including the emergence of minerals, the atmosphere, plants, and animals. Ultimately, in Part III, these concepts will also form the theoretical basis for an ethics of living well in the Kinocene.

FLOW

The earth flows. This is the first and central thesis from which the entire conceptual framework of geokinetics follows. What must the nature of the earth be to make it capable of being in the unstable motion we see so prominently today?

Etymologically, the earth is literally dirt. But where did this dirt come from to make it capable of continual terrestrialization? What are the historical, material, and kinetic conditions such that the earth came to be dirt? This dirt is no native, but a cosmic migrant. It is already part of a much larger flow of matter that we need to take seriously.

The earth is matter thrown into motion. Without the constant thermodynamic flow of energy from the universe, there is no accumulation, dissipation, or recombination of matter into a stable earth. The thermodynamic transfer of energy into and out of non-equilibrium states is what has allowed the earth to emerge, persist, and distinguish itself from other aspects of the cosmos. But the flows of matter that composed the dirt of the earth also have their own conditions that take us further back, to an even more mobile flow of matter.

Before the Big Bang, 13.8 billion years ago, when the universe was younger than 10–43 seconds old, there were only indeterminate quantum fluctuations. These fluctuations occurred at a size smaller than the smallest measurable length (1 Planck length) and at indeterminately high temperatures. There was no void; no metaphysical singularity; no stasis. There was not even movement in the traditional sense of something moving from point A to point B in space, either. There was no space or time.

Yet there was matter as energy, and there was motion as a continual transformation of the whole. There was no stable background of spacetime, no ground, and no foundation upon

which the Planck Epoch could have emerged. Matter was neither this nor that, neither here nor there, neither continuous nor discontinuous, but pure indeterminate flux.

Before the Planck Epoch, the universe was neither random, determinate, nor probabilistic. The cosmos was neither one nor many because its energy was as indeterminate as its position and momentum. The laws of physics had not yet emerged, and even the conservation of energy could not be guaranteed.

In cosmological time, we can call this the "Indeterminate Epoch." Through completely relational and nonrandom processes of its own, energy began to iterate itself into a single Planck-sized pattern called the Planck Epoch. This was not a singularity, "cosmic egg," or "primeval atom," as the 20th-century astronomer Georges Lemaître thought.[4] Instead, it was the first emergent form of the universe: a fluctuating but metastable region of spacetime with the smallest size and highest temperature theoretically measurable.

This flux and flow, however, were still too small and hot for the four fundamental forces, including gravity and electromagnetism, to be divided from one another. So they remained continuous aspects of the same flow. This is what cosmologist call the "Grand Unification Epoch."

Around 10^{-32} seconds after the Big Bang, a rapid inflation of spacetime occurred in which an enormous amount of spacetime unfolded from this cosmic flux. The universe expanded to 10^{78} times its previous volume, or the equivalent of going from 1 nanometer to 10.6 lightyears long, in a fraction of a second. Again, this movement was not a spatiotemporal movement of something across or against a fixed background of spacetime—it was an expansion of spacetime itself. In other words, the flow of the universe was not a movement from here to there but, rather, the

creation of the here and there. There was no extensive movement of *something*, but the immanent kinetic unfolding of the universe into and out of itself.

Then came the Inflationary Epoch, the production of spacetime itself—the material condition of all discrete beings. Since light moves through spacetime and not the other way around, inflation flowed faster than the speed of light.

One of the most important, although not yet experimentally demonstrated, ideas in theoretical physics today is that spacetime is an emergent feature of a moving universe. In other words, spacetime is not a substance or force but a metastable process. It is like the "bubbles" or "foam" stirred up by a more primary turbulent process of quantum matter in motion.[5] What physicists call "quantum gravity theory" is the attempt to provide a quantum theory of spacetime and thus unify the main frameworks of theoretical physics: quantum physics and general relativity.[6]

This is a dramatic and perhaps abstract-sounding way to begin to rethink something that is, to us, the most concrete: the earth. However, the indeterminacy of the universe is a crucial first step in rethinking the earth as a process. The indeterminate flow of the universe is the immanent material condition of the earth. It shapes the way we think about what earth processes are, that is, material processes with a genuine capacity for novelty and motion. Starting from quantum cosmology, then, we should expect, rather than be surprised by, the mobility and instability of the earth.

Einstein's cosmology of a static spherical cosmos assumed spacetime but did not explain its emergence. In this way, it was much like older geological models that assumed a stable primordial earth but did not explain it. Similarly, early cosmologies of the Big Bang assumed a uniformly expanding universe, just as geologists believed in a uniformly moving earth.

These old geologies and cosmologies also have parallels in the philosophical ontology of time that treats time as universal and given.[7] Growing up in the Holocene, humans have had a long terrestrial bias for stability.[8] Is it possible that our philosophical, religious, and scientific pretensions to universality and stability have arisen from the extremely particular geokinetic situation that is the Holocene?

The cosmological theory of sudden chaotic inflation,[9] the indeterminate fluctuations of quantum gravity,[10] and discoveries of the earth's sudden and unpredictable climate history[11] have overthrown these old cosmologies, geologies, and philosophies. I argue here that a much more fitting philosophical perspective for our time is that of motion.[12]

Why should we continue to model our philosophies on foundations, our cosmologies on background spacetimes, and our geologies on Holocene uniformities, when the evidence is pointing us in the opposite direction? Our earth is not a ground, but a tiny metastable region of an unstable and dying universe.

We have got the problem entirely upside down. We shouldn't shake off our anthropocentrism in favor of bio- or geocentrism.[13] There is no privileged Archimedean point and foundation for knowledge. Because we have taken the earth to be a stable and uniform place, we have imagined that our universe must be similarly stable and that it must all come from some static unmoved mover, God, void, or homogeneous theological singularity. The outrageous lengths to which humans go in order to explain movement by something else never ceases to amaze.[14]

Rarely do geologists or philosophers extend their thinking to the origins of the universe more broadly. When they do, their reflections are often out of date or limited to our solar system. But the increasing shift in physics from substances (spacetime) to

kinetic processes (quantum gravity) should also prompt us to reconsider substance-based approaches to the earth sciences and philosophy.

The oft-cited theory that before the Big Bang, there was nothing, and then afterward, there was something, is typical of substance-based and dualistic metaphysics.[15] In the beginning, there was stasis, and then there was movement. This story hardly moves beyond Aristotle's unmoved mover. The only real alternative, in my view, is an indeterminate process cosmology without beginning or end, stasis or movement, being or nonbeing.[16]

Our metastable earth is the product of indeterminate cosmic flows. It is their regular flux and flow that continually supports and reproduces every inch of our spacetime. The geological transformation of the earth is part of the same continual alteration of the universe. We live on an earth in which the matter of the cosmos is deeply entangled. For example, indeterminate quantum ripples in early spacetime eventually developed into later galaxy clusters and planets like ours. Many of the earth's most important physical and chemical changes are related to processes outside the earth and even outside our solar system.[17]

The enormously crucial takeaway from these indeterminate quantum fluctuations is that they change our whole conception of what the universe is. We live in one big fluctuating metastable process, without beginning or end.[18] The earth is not an exception to the rest of our unstable and fluctuating universe. From this starting point of indeterminate flows, a whole new theoretical framework for thinking about the earth can emerge.

MATTER

The earth flows and moves; matter is what is in motion. However, matter is not a substance. "Earth" is "dirt, soil, or material," but soil is not static stuff. Soil is exceptionally mobile and heterogeneous. Soil is the ground of the earth. However, it is the most visibly unstable and shifting kind of ground because it is made by erosion and decomposition.

Soil is a kinetic process composed of traces from deep cosmic and terrestrial time: minerals, liquids, organic materials, gases, and organisms. Soil is composed of the earth and recomposes the earth by regulating the atmosphere, supporting life, and storing water. Soil is the earth composting itself, and dirt is the co-creation of all the earth's processes, continually transforming one another. It is billions of years of cosmic and terrestrial history in motion.

How arrogant that we ever spoke of the earth as a static or passive ground, an "immovable ark,"[19] or foundation for anything, when the whole thing is fluctuating compost. How could we ever have talked of a geology or geography of "the" earth when a single handful of dirt offers such a simple material demonstration of its deep and mobile history?[20]

In a single handful, we hold our atmosphere, our minerals, life, and death. Soil is a bit of our terrestrial and cosmic deep past. That the most apparently stable of all objects (the earth) is phonetically identical with the most mobile (earth) is a beautiful lesson. That which the ancients most maligned as being at the bottom of the great chain of being (earth) is also the concrete foundation upon which they stood to model the spherical cosmos. The earth was both the condition for the geocentric cosmos and the filthy material soil that covered their feet.

But the earth is not a sphere, and neither is the universe. The earth is more like an eddy in a river through which flows of matter continuously stream. It is replenished and depleted in a vortical cosmic dance. "The world is a vampire," as The Smashing Pumpkins sang: a vampire living from the death of the sun. The universe must die to keep living.

Before Aristotle, there was no word to designate "matter in general." This is because matter was not a substance, stuff, or kind of thing, but a process frequently associated with weaving in archaic Greek culture.[21] Aristotle appropriated the older Greek word *hyle*, meaning "firewood, wood, or forest" and redefined it to mean "substance or stuff in general."

In this way, the term *hyle* went from meaning something earthly and mobile—growing, decomposing, and composing—to being a passive substrate molded by ideal forms and laws of nature. Earth and matter have suffered the same fate in the Euro-Western tradition. The return to one also suggests a return to the other. A new theory of the earth thus calls for a new theory of process materialism in which matter is again an earthly flow.

We cannot correctly understand the earth as a being because it is a becoming. Trying to determine the being of matter is a similarly flawed approach. Matter neither is nor is not, but flows, folds, and circulates. Matter is not a being but a becoming. The quantum theory of matter, for example, at least in some interpretations,[22] is neither an empirical nor a metaphysical definition. It is an historical-ontological description of matter as indeterminate.

In the West, matter is the historical name of what is in motion. Matter and motion stand together at the bottom of the great chain of being in the dirt. They are less like static beings than anything

above them on the chain, and that is because they are not beings at all. They are dirty becomings, whose "being" continually changes as they change and who therefore have an "indeterminate" being.

This is also why the moving earth is not identical to itself. It is a geokinetic material process, not a substance or subject. Geokinetics is, therefore, a kind of "kinetic materialism." In this book, I treat the earth not as a discrete, deterministic, or probabilistic being but rather as matter-in-motion, that is, as an open relational process without fixed characteristics or essences.

Matter is what is in motion, but matter is not reducible to motion. Motion in itself, without a determinable matter, is a pure and immobile abstraction.

Matter and motion have suffered a shared fate in Western history.[23] Western culture has almost always subordinated them to some higher category. In classical Greece, matter and motion were subordinate to eternal forms and unmoved movers. In the medieval world, they were subservient to the vital forces or *vis inertia*, which directed their motions and formed their matters. Finally, in the modern world, they were subordinate to mechanism, rationalism, and natural laws.[24]

And just as matter and motion share a subordinate position, they also share a possible twin liberation. If motion is ontologically primary, as I argue, then so is the matter that moves. If matter is fundamental, then so is its motion. Without matter, the concept of movement remains a "false" or idealist category.[25] Without movement, matter remains static, discontinuous, and dead.

This book uses the idea of kinetic materialism to rethink the earth as a process.[26] If the earth is a material process, then it cannot be adequately defined as an object or a subject. We need a new, process-based, framework. All "universal" ideas of matter

come from material and historical beings in motion on the earth. Even the belief that matter and the earth are relatively passive bodies is possible because of the relatively stable Holocene period.

Kinetic materialism is, therefore, neither a Copernican revolution, in which it is we who move around the stars, nor a Ptolemaic counterrevolution, in which we are at rest while the stars move. It is a Hubblean revolution, where everything is in motion. This is not a reductionistic theory of matter, because there is no single idea of matter that can define it once and for all. Matter is an open process of motion whose being changes as it moves.

For matter to become earth, it must be able to flow. Thus, I propose that material flows are a good starting point for rethinking the earth.

Pedesis

The earth is, first and foremost, cosmic matter on the move—migrant dirt. Geologists call the soil of the earth the "pedosphere," from the Greek root *-ped*, meaning "foot, track, earth, or ground." The pedosphere thus deserves special attention because it contains, mixes, and composts all the other spheres: lithosphere, biosphere, hydrosphere, and atmosphere. The pedosphere is not just one spatial region of the earth among or between others.

The pedosphere is the concrete place where all the other spheres break down, commingle, mix, and directly coproduce one another. The pedosphere is a kind of woven, braided knotwork where the other spheres touch, translate, and transform one another. The pedosphere stores and releases carbon, regulates water distribution and filtration, and makes minerals available to the surface. Plants and animals, including humans, are made of pedosphere.

In one sense, the pedosphere is the place where particular creatures walk: the ground. In this sense, it is a frequent site of direct physical composition and decomposition. It is the place where the tracks and traces of terrestrial entanglement are impressed on the surface. It is where waste becomes food for mobile life. It is where the sky leaves a memory of its movement through precipitation and where rock leaves a souvenir of its tectonic path. It is the place where the earth walks, moves, and wanders. The pedosphere is the foot of the walker and the ground that walks and is remade by walking.

In another sense, the pedosphere invokes a much larger movement of the earth itself as a planet, from the Greek word *planáō*, "to wander." The pedosphere is not just terrestrially but cosmically mobile. The earth walks a path through the solar system. Its orbit is not strictly circular, elliptical, or regular. The earth is an eccentric wanderer. It shakes itself with quakes; it moves off its rotation. Its orbit around the sun varies in eccentricity between more circular and more elliptical in response to the irregular orbits of Jupiter and Saturn. All the planets are wanderers, swerving together in vast cycles and epicycles, each lasting hundreds of thousands of years.[27] Each cycle is a unique iteration.

The earth even leaves a trail or trace of heat as it moves through the solar system and distributes the sun's radiation. And as our solar system moves through the Milky Way, it also moves up and down through the gravities of other star systems and asteroid belts, further changing planetary orbits and bombarding our planets with asteroids. Many of these eccentric movements are not just unknown; they are fundamentally chaotic and unpredictable.[28] It is even possible that a large disk of dark matter in the Milky Way may have affected the earth's climate history and caused the extinction of the dinosaurs.[29]

Therefore, in another sense, the pedosphere also refers to the pedesis or errancy of the earth's motion. The word "pedesis" (again, from the Greek root *-ped*) refers to the motion of self-transport: the motion of the foot in walking, leaping, running, dancing unpredictably. Flows of matter have no straight lines because they move pedeticly.

The discovery of pedesis comes from two of the most critical kinetic discoveries of 20th-century physics, Einstein's kinetic theory of matter (1905) and Heisenberg's quantum uncertainty principle (1927). In the first, Einstein argued that all matter is a product of the stochastic or pedetic motion of atoms. For example, the atoms in gases move faster and farther than those in fluids. Those in fluids move faster than those in solids. All matter, Einstein showed, was not only in motion but in pedetic or turbulent motion. The form of matter is fundamentally kinetic but also fundamentally and irreducibly turbulent.

However, by showing that all matter was in turbulent or pedetic motion, Einstein introduced a fundamental kinetic uncertainty and unpredictability into the heart of matter. Although the description of kinetic turbulence goes back to the Roman poet Lucretius, science has been entirely unable to produce a successful predictive theory of turbulent motion beyond minimally probabilistic models. The precise kinetic structure of turbulence remains one of the last unsolved problems of classical physics, with a current million-dollar prize for its mathematical solution.[30]

The unsolved problem of classical turbulence, combined with Einstein's kinetic theory of matter, has enormous consequences. All matter is in motion, and that turbulent motion is not deterministically solvable. Heisenberg supposedly once said that he wanted to ask God two questions.[31] The first was, "Why is

general relativity so weird?" and the second was, "How do you explain turbulence?" He then said that he was certain God would know the answer to the first question.

In the second kinetic theory, Heisenberg showed that there is a fundamental limit to the precision with which we can know the position and momentum of a particle at the same time. The more precisely the position of a quantum field is determined, the more it looks like a stable particle, but the more its momentum becomes uncertain. Conversely, the more closely we determine the momentum, the more its position becomes uncertain.

In other words, the precise extensive path of a particle from A to B is fundamentally uncertain. There are different interpretations of this experimental finding. However, one consistent interpretation is that the human observation of the position or momentum of an electron with light (photons) is only one influence among others in the world that can directly affect the momentum of quantum fields.[32] If this is the case, then humans may not be the only observers to produce uncertainty.

The importance of these discoveries is that matter and motion are indeterminate at both classical and quantum levels. If the earth is matter in motion, then it is also subject to a fundamental indeterminacy. We should, therefore, take this seriously as a methodological starting point for a materialist theory of the earth.

RELATIONAL MATERIALISM

Pedesis might be irregular and unpredictable, but it is not random. Through the pedetic movement of matter, metastable formations emerge. Terrestrialization is a metastable process. By contrast, the ontology of randomness is quite bleak. In such an ontology, all matter would be moving randomly at all times, unaffected by any other matter. Since fluctuations from disorder to order are physically rare, the likelihood that anything like the sun or even our galaxy would suddenly pop into existence would be unimaginably rare. And it would then likely immediately fall apart due to further random motion.

The very idea of purely random motion presupposes that it was not affected by anything else previously because, if it had been, its movements would not be completely random but instead caused in some specific way by something else. Randomness presupposes a first thing or motion before which there was nothing. This is a version of the internally contradictory hypothesis of ex nihilo creation: something from nothing.[33] Given the high level of order and complexity in the present cosmos, this kind of pure randomness is demonstrably not the case.

Pedetic motion, on the other hand, is not random at all but emerges from and is influenced by other motions, just not in a wholly determined way. Pedetic movement is challenging to predict not because it is random but because it is so entangled with all other movements. It is the interrelation and mutual influence of matter with itself that causes its unpredictable character. Over a long time, the pedetic movement of matter combines and stabilizes into specific patterns and relations, creating metastable structures of stability and solidity. Then, after a while, they become turbulent again.

Absolute randomness would require a motion to be wholly unaffected by and thus unrelated to any prior movement that might affect its subsequent action in any way. This would be a nonrelational object. Nonrelational randomness and relationality are incompatible with each other. The notion of randomness is a logical category, a pure mathematical idealism, as if we could abstract matter from its motion and kinetic relations. We have no evidence for anything truly nonrelational in the universe. If all matter is relational to some degree, then it cannot be truly random.

Pedesis, then, is simply a degree of more or less ordered relations of motion. Turbulence, for example, is matter in motion with a very high degree of unpredictability as a result of the number of continually changing variables involved in the process. Yet turbulence also has relatively ordered patterns, spirals, swirls, vortices, and so on, which begin to emerge from these continually changing relations.

Matter is pedetic not only at the quantum level of indeterminacy. It is pedetic also at the atomic, molecular, meteorological, and cosmic levels. Pedetic motions crystallize into relatively ordered patterns at every level of nature—even if it takes millions of years. Pedesis always generates some order.[34] Matter in motion is always related to other matters in motion. Therefore, there is never a case of absolute determination or absolute randomness. Pedesis gives rise to more or less stable configurations, like the electron patterns of the atomic elements, the speed of light,[35] or the rate of acceleration at which things fall on the surface of the earth.[36] Clearly, we do not live in a random universe. The mathematics of probability is our way of making educated guesses about the future based on past events.

There are thus two factors barring absolute determination and absolute randomness, and both have to do with motion. Absolute determination is not possible because we do not and cannot have a perfect knowledge of all the material variables in the universe, since the universe is continually expanding and changing. There is no meta-object called "the universe." And absolute randomness is not possible because since all matter is kinetic and relational, it cannot be truly random. If all of matter in motion were truly random, there would be no universe, and nothing would hold together for very long.

This relational indeterminacy is what produces the ordered metastable patterns we study in the earth sciences. Pedetic air currents whirl motes of dust around a room and pedetic orbits whirl our planets around the sun. Spiraled rings of smoke swirl up from a cigarette and thunderstorms swirl up around the globe.[37] The earth is a vast, metastable process of metastable processes. This is the earth I would like to study in this book: the earth of indeterminate flows of matter. This is an earth made of flows and folds, as we will see in our next chapter.

2

The Fold of Elements

THE FLOW AND FLUCTUATION of matter constitute the earth and its elemental body. The word "earth" refers to the planet Earth *and* its earthy soil, but also to the classical element "earth." The earth is elemental in the sense of being everything that is not air, fire, and water but also in the sense that it is composed of "elemental" or "primordial" components.

What is an element? If we are going to take the materiality of the earth seriously, we need to know what it is made of, its elemental constituents. This chapter aims to answer this fundamental question.

To begin with, the earth is elemental and elementary because it is of an elemental universe. The earth is burnt-out star-stuff from the early universe, from 13 billion years ago. Elements do not preexist the cosmos but emerge through it as it flows. An element, then, cannot be a fully discrete particle, atom, or fundamental building block of nature. Particles are merely the products of a more primary material flow that began to fold back on itself. An element is a fold or pleat in matter.

An element is not just a constitutive or simple component. An element is an emergent process that came to be through the iteration of fields of energy. So-called "fundamental particles" like fermions and bosons are not, technically, actually fundamental—their existence already assumes space-time and energetic movements high enough to produce both spacetime and particles

in the first place. This is why the first 10–13 seconds of the universe contained no fundamental particles. Particles emerged from processes.

During what cosmologists call the "Inflationary Epoch," spacetime fluctuated so wildly that it could not sustain any relatively discrete regions or elements. Due to these primordial quantum fluctuations, spacetime did not flow homogeneously but rippled with gravitational waves. As the waves moved, they cooled down into dendritic patterns, the way that a river sheds its water into tributaries and pools. These metastable pools of energy created the earliest and heaviest particles (quarks, hadrons, neutrinos, and leptons). Each particle unfolded out of the previous, like the petals of a flower from a bud.

It is a common misconception to think of particles as discrete objects, when they are nothing of the sort. They are vibrational patterns in the energetic topology of the universe. If spacetime in quantum gravity is like a continually fluctuating "foam," then elementary particles are the regions where this foam has coalesced and folded into giant metastable bubbles.

Elementary particles are excitations in fluctuating quantum fields. What makes them elemental is not that they were first but that they were emergent regions of an indeterminate material flow that interacted with itself. This self-interaction is what I call an elemental "fold."

The early universe was fluid. Quantum perturbations and gravitational waves rippled like the surface of a pond in a tropical rainstorm. What we now call "dark matter/energy" also emerged at this time and still composes 85% of the universe. We know this only indirectly, of course, because we cannot empirically measure the quantum fluctuations that make up this dark process.[1] Throughout this turbulent and chaotic inflation, dark matter was distributed and diffracted unevenly across the cosmos. As the

universe cooled and became less fluid, these uneven distributions became the regions where visible matter accumulated into little vibrating and diffracted pools in the form of particles, atoms, molecules, stars, planets, and galaxies.

Inflation eventually made the universe almost entirely flat and homogeneous, like a folded-up blanket smoothing itself out, but with little ripples still left here and there. However, since inflation involved the unfolding of quantum processes, the precise spacetime in which chaotic inflation slowed down was indeterminate.

This resulted in small deviations from perfect uniformity in the inflated spacetime that now shaped the whole structure of the universe, including us and our planet. The earth was born from a tiny indeterminate quantum fluctuation long ago during inflation. Quantum cosmology is undoubtedly one of the most mind-blowing and revolutionary discoveries of the last few decades. It, too, should be taken seriously as part of the earth's deep history.

FOLDS

Matter tends to flows turbulently and to fold itself up into metastable cycles. These are what I am calling "elements," in a broad conceptual sense. Elements are thus both atmospheric processes and relatively discrete regions where larger composites emerge. Folding is nature's way of self-differentiation and self-affection.

These elements are flows that sustain themselves through iteration. The condition of earthly terrestrialization is, therefore, the periodic folding of material kinetic flows at different frequencies. The earth iterates itself in water cycles, rock cycles, and carbon cycles because the universe is already based on cycles.