IF YOU CAN SEE TIME

A Geologic, Historical, Literary, and Personal Journey through Deep Time

by

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Certificate of Approval

This is to certify that the accompanying thesis by Anna Malka Murveit has been accepted in partial fulfillment of the requirements for graduation with Honors in Environmental Humanities.

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Kathleen Shea

Whitman College
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Dedicated to all natural philosophers
and a few in particular

INTRODUCTION

In an introductory geology class at Whitman College in 2010, my professor mentioned that geology bordered on the humanities. By this he meant that it is an interpretive science—one without the hard drawn exactitudes of chemistry or physics. Geologic processes can only be *estimated* by equations. We model, approximate, and interpret. Over four years of undergraduate geology, I have discovered further interactions between the two disciplines. Geologists must have active imaginations. We must be able to make connections across our broad discipline and tie conclusions to the big picture. As a fundamental part of our research, we find ourselves sketching beautiful landscapes. Many rocks and minerals have an undeniable aesthetic quality. Most importantly, you cannot be a geologist without certain moments of confounding awe concerning the concept of geologic time.

In this thesis, I have borrowed the now archaic term, "natural philosopher," to describe thinkers whose scientific discoveries and understandings are tied to meaning in the human experience. I can be sure that not all scientists think in this way, prioritizing meaning, rather than progress or precision. What's more, journals

and scientific societies that publish research no longer have a place for the humanities. Flowery descriptions of landscapes like Clarence Dutton's *Tertiary History of the Grand Canyon* or philosophical reactions beside theories as seen in James Hutton's *Theory of the Earth* no longer fit the protocol of major scientific publishers. I am convinced that the absence of discourse about the human experience in the mainstream scientific community, and particularly in discussions of technology, leads to dangerous, dehumanizing, and environmentally degrading results.

However, this thesis is not about atomic warheads, genetic engineering, or fossil fuels. It is the documentation of my personal journey toward becoming a natural philosopher, of becoming a scientist while trying to make meaning out of the an arena that is usually reserved for the materialists. There is something in this world that is unable to be articulated with words or numbers, and I think that old world natural philosophers wanted to explain the earth's processes to get closer to an understanding of the incomprehensible.

In the attempt of wrapping my head around the concept of "deep time," the vast expanse of geologic history, I discovered other writers, professors, and friends who were on a similar journey. In this thesis, I have tried to compile a record of my thoughts and the thoughts of others influenced by deep time who have wrestled with the belief that there is more than just the materialistic truth that we have gained through science. As Emerson wrote, "It is not that we believe concerning the immortality of the soul, or the like, but *the universal impulse to believe*, that is the material circumstance, and is the principal fact in the history of the globe." I have

attempted here to have conversations about belief, meaning, and personal significance with authors, teachers, and peers whose worldview has been shaped by faith in the geologic principle of deep time.

In Chapter One, I blend a personal essay about discovering time with a historical and literary discussion of James Hutton, the man who discovered it. I introduce how the modern discipline of geology began when it became clear that time was incomprehensibly vast. My personal narrative parallels Hutton's discovery that the present is the key to the past. Hutton also helps me to introduce another important thread—the way human beings look to nature for answers and to find a figure of authority, or perhaps, a teacher. In nature, Hutton saw wisdom, system, and consistency. His observations supported his deeply held belief in Nature's benevolence and intentionality. According to Hutton's understanding, Nature's constant flux and other natural laws must therefore benefit all life. However, despite the vast and unknowable immensity of time that Hutton saw in the rocks, he did not lose faith in the significance of his own life or in the comparably short range of time in which he believed human beings had existed. Hutton rested assured that Nature's good purpose resulted in the creation of life, habitat, and natural systems. In this system, where all things were intentional, human beings had a purpose too—to utilize the intellect nature provided to figure out how all had come to be and to use the senses to relish in its beauty.

Chapter Two begins with a darker tone. Nineteenth century scientific achievements complicated Hutton's idealism. Extinction alone would have baffled Hutton, but natural selection, a theory proposed by Darwin as the primary driver of

evolution that has held its ground for over 150 years, ruled out the possibility of preordained purpose. Under Darwin's theory, species acquired traits and evolved by way of variation, a random happenstance. If these arbitrary traits happened to be useful for finding food or having sex, they were naturally selected for and passed on to offspring. According to Darwin, that was it. Though he could not finger genetic mutation as the cause of variation, he was sure it was completely random. Charles Darwin believed that in evolution there was no direction and no end; therefore, he accepted that humans could not be a special species with an immortal soul, God-given purpose, or afterlife. As Darwin wrote about his own life, he described how almost against his will, his orthodox beliefs in Christianity faded to agnosticism. His scientific ideas became incompatible with his conception of God. Whereas Hutton could find meaning in his connection to the divine through his own intellectual purpose, Darwin became disconnected a sense of purpose and isolated from meaning, living in a materialistic world in which each human life was irrelevant to the whole of nature.

I then describe how Loren Eiseley might help us out of Darwin's surrender by way of an unorthodox understanding of spirituality. A scholar in evolution and Darwin himself, Eiseley understood the materialistic implications of Darwin's theory, but reoriented his spirituality by way of connection and love. He described an epiphany, which allowed him to imagine the extinction of humanity. He came face to face with a fossilized skull in a slot canyon and stared up at the blue slit of sky as the world carried on and the sediments piled on top of the record of human beings. However, rather than resignation in the inevitability of human extinction, he asked

the reader to feel pride in the thread of connection that weaves haphazardly through evolution from the start of creation to us and beyond in the unknowable, but inevitable future. For Eiseley, this connection was religious. For him, the unending mysteries of Earth offered humility. He too believed that some things would never be fully explained, such as the spark that began life on Earth.

In Chapter Three, I present the journey of my professor, Kirsten Nicolaysen, which hints of Hutton and Darwin as she seeks to understand the world by way of experience, rather than the biblical literalism of her family. Her academic and professional career has afforded her intense experiences with time. One moment in particular stands out for Kirsten as her first visceral connection to time. She and a crew drilled through 520 meters of nannoscopic fossils in the East Indian Ocean. This, she reported, was the first time her mind began to recognize the vastness of time as more than just an abstract academic concept. She reacted with awe and still gets goose bumps when she thinks about it. Though fiercely empirical, Kirsten still finds the spiritual journey to be important. Her comfort in the immortality of biogeochemical cycles is, for now, the way she understands meaning by way of connection.

Chapter Four is a personal narrative of my own journey of wresting with a belief in two seemingly incompatible scales of time, the human and the geologic. It chronicles my experiences with rocks that have forced me to reexamine this dichotomy. A fieldwork position with the USGS brought me to Mt. Rainier where I learned about the concept of scale.

Chapter Five brings the narrative to the present moment by way of Gary Snyder's poetry and my most recent confrontation by rocks in the Utah desert. Snyder's *Mountains and Rivers without End* is a book of cohesive poems, written over a lifetime of journeys and deals principally with the Chinese character *k'ung*, which means, depending on the context, either emptiness, sky, space, or the void. For Snyder, a Buddhist and environmental activist, emptiness is of utmost importance because, as stated in the book's epigram, "The notion of emptiness engenders compassion." His poetry shows how if an awareness of *k'ung* can be achieved, then compassionate action will follow.

The Chinese landscape scroll that Snyder described in his first poem follows me to Utah, where I found myself following a similar path through a dramatic landscape. Having never been to Utah, the naked rocks of the desert surprised me. I experienced all ranges of emotion from ecstasy to loneliness. The temperature varied from in its days of warmth, running on red rocks, to long, cold, nights in darkness. There were times when I felt connected and times when I felt excluded. There were moments of understanding, moments of wonder, and moments of loss. At one point I thought I never wanted to leave, and another I decided I never wanted return. The desert was is another place to confront dichotomies, such as that of geologic and human time. Though I personally failed to find resolve and connection, Snyder's *Mountains and Rivers without End* offered me a different approach. In one of his poems, Snyder invites the reader to step back and look at the land with a different perspective—to notice how human beings walk on a planet, which is also in motion, asking us to step back from the dichotomy and see that we are all

connected in one continual flux. He communicates how no individual can exist without its connection to all other things. In this loss of individualism, the acceptance of emptiness, compassion for all beings emerges.

I do not find it ironic that my scientifically oriented major has turned me into a philosopher. Deep time is provocative, and it is worthwhile to scribble down our spontaneous impressions in field notebooks beside observations and interpretations of outcrops and landscapes. The vast expanse of geologic time will always evade my grasp, but nonetheless, I have found that though the exercise of meditating on deep time is at first uncomfortable, it is of great importance for myself, for humanity and for the protection of all life and landscapes.

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Time, which measures every thing in our idea, and is often deficient to our schemes, is to nature endless and as nothing.

James Hutton, *Theory of the Earth*, 1788

Walking on walking,
Underfoot earth turns.

Streams and mountains never stay the same.

Gary Snyder, *Mountains and Rivers without End,* 1996

Once in a lifetime, perhaps, one escapes the actual confines of the flesh. Once in a lifetime, if one is lucky, one so merges with sunlight and air and running water that whole eons, the eons that mountains and deserts know, might pass in a single afternoon without discomfort.

Loren Eiseley, *The Immense Journey,* 1946

CHAPTER ONE

Discovering the Abyss of Time

> There are, in the constitution of the world, which we now examine, certain means to read the annals of a former earth.
>
> James Hutton, *Theory of the Earth*, 1788

Following Highway 19, the John Day meandered north along Fossil Beds National Monument. Through the window, my eyes followed the river as it cut through its namesake geological formation, a colorful unit exposed in badlands topography. Its crumbling mounds were smeared with pastel shades of white, pink, grey, blue, red, and yellow. As the river passed the Thomas Condon Paleontology Center and Historic Cant Ranch, the broad valley narrowed into a short canyon of hard stone. On both sides of the valley, the river had exposed a gravely sedimentary rock, the Goose Rock Conglomerate.

Goose Rock is an old-school exposure, cropping out without the work of human hands. Early pioneering geologists like James Hutton and John Wesley Powell only saw what lay beneath their feet where water had carved canyons, cut banks, and sculpted sea cliffs. Today, geologic mapping is more easily accomplished by car than canoe. As engineers blasted through hillsides to create the extensive

highways of the United States, our geologic history became clear. Drive up to any road cut, and you can see a sliver of geologic time.

Our van pulled onto the right shoulder of the two-lane highway between the road and the river. Fifteen students and our professor, Pat, unloaded. The morning light shone brightly on the sheer cliff face across the road. My friend, Mattie, and I were the last to exit the vehicle. We yawned, stretched, and skeptically surveyed the rock from afar. We pulled out our field notebooks and jotted down a few observations before filtering across the deserted highway.

Up close, Mattie and I saw that the brown cliffs were made up of gravels and cobbles, cemented together. With a bit of imagination, we could make out sediment sorting into rough layers by size. Each messy row ranged from ostrich eggs to marbles.

I pulled a hammer from a white bucket on the shoulder and began to wail on the rock, smashing at a fracture until a fresh piece came loose. An oblong slab fell at my feet. I fished a hand lens out of my pocket and reached down to pick up the hand sample. With the lens close to my right eye, I brought the rock up to my face and examined it carefully. I handed it to Mattie with eyebrows raised. We were supposed to be able to interpret this rock, to read some narrative of its history from its components. In between the stones, Mattie pointed out a matrix of tiny sand grains that held the rock together. As she scraped at it, the rock held solid, shaving her fingernail slightly like an emery board.

We agreed that some things about this rock were familiar: the array of colorful, round stones, their layering, the way they all seemed to lean in a similar

direction. My eyes panned past the bus and over to the John Day River. I bet Mattie that I could find a similar assemblage at the bottom of the stream. Goose Rock might be a fossilized river, I realized, the cliff a series of buried channels, hundreds of river migrations stacked on top of each other. There, preserved in the cliff before me was row after row of gravels and sand, all pointing down current of some ancient stream.

"What do you see?" Dr. Patrick Spencer boomed, his eyes undoubtedly twinkling behind circular tinted lenses. We formed a semicircle before him as the professor began to wave his arms. Drawing from his own observations and the local geologic context, he spun his interpretation as if it were a legend, speaking as if he were passing down the oral history of a sacred place.

"You know where we'd be standing if we were in the Cretaceous?" He quizzed and scanned the collection of Carhartt-wearing sophomores and juniors, baiting a response. "We wouldn't be standing at all… We'd be treading water! You know, here we are in modern day central Oregon, freezing our butts off, but a hundred million years ago, we'd be floating in a shallow sea that covered most of Oregon. It would be the perfect climate to swim!"

These large river rocks indicated to Pat that this rock formation had been formed by a delta on an ancient shoreline; these stones could not continue once the river met the sea, and formed a wide, sloping deposit of rounded rocks. We stood near the beach of the ancient Pacific Ocean. One hundred million years ago, a powerful river ran from a now non-existent mountain range to the ancient beach near Mitchell where it dropped off these rocks as the river slid into the sea.

The process made sense to me. I could see how fans of river cobbles might have formed as they cascaded down some former mountain and into the shallow water. After all, it had looked familiar; I had seen similar deposits as rivers flowed into beaches back home in California. What did not register in my mind was the age. I lacked a reference point, a conceptual scale against which to measure a hundred million of anything. One hundred million years did not stick. The number's meaning was lost. Then, I did not yet notice my shortcoming. Without blinking an eye, in my field notebook I wrote the following words:

> Cretaceous (Late Mesozoic)
> 100 million years ago

~ - ~ - ~

Most geologists know James Hutton as the father of the modern discipline and a hero of empiricism. He was the first in the Western scientific tradition to boldly speak to the unfathomable depth of geologic history. Hutton was keenly aware of the religious and psychological impact of geologic time. This new temporal context directly contradicted the prevailing scientific and Christian view of the world. In Hutton's words, "first sight [of physical evidence of deep time] may fill the mind with wonder and with doubt." Perhaps, as paleontologist and scientific historian Stephen Jay Gould has claimed about the discovery of deep time, "All geologists know in their bones that nothing else from our profession has ever mattered so much."

All Christian churches until the eighteenth century believed that the Earth was not quite 6,000 years old. This was an age based on tedious biblical analysis, which began around 325 AD with Eusebius's chronologies of world history and the history of the Christian church, presented to and approved by Emperor Constantine. During the intellectual revolution of the eighteenth century, Sir Isaac Newton was one of many who used modern methods of science to constrain the history of Earth to this calculated timescale. In order for so much to form in such a short amount of time, renowned German mineralogist, Abraham Gottlob Werner, published the "universal ocean" theory. This idea, based on few catastrophic events, aligned with the stories in Genesis of Noah's flood or of creation itself: "God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear; and it was so." Werner theorized that as the universal ocean disappeared, the land below appeared, precipitated, and formed.

James Hutton was a contemporary of Werner's, and ultimately became his academic opponent. Hutton lived in Scotland during a period pervasive literacy and advancement now known as the Scottish Enlightenment. It was a time of inspiration and collaboration of figures such as David Hume, Adam Smith, Robert Burns, Adam Ferguson, Joseph Black, John Playfair, James Watt, and James Hutton with periodic visits from the likes of Benjamin Franklin and Erasmus Darwin. The scientific experimentation and philosophical outpouring led to the formation of many modern disciplines including economics, history, sociology, geology and chemistry.

Hutton graduated a doctor from the University of Edinburgh, but for a variety of reasons, which likely included his desire to be out of doors, he ultimately changed

paths and began to study agriculture. He moved to Norfolk, England and stayed with a farmer from whom he studied husbandry. Though he spent most of his days on that farm, he made many journeys by foot around the country to learn about agriculture. These trips peaked Hutton's interest in geology and mineralogy. His contemporary and biographer, John Playfair, accounted in 1803:

> In a letter to Sir John Hall, he says that he was become very fond of studying the surface of the earth, and was looking with anxious curiosity into every pit, or ditch, or bed of a river that fell in his way.

Hutton also traveled through Holland and Belgium to learn traditional husbandry methods from the best before he ultimately returned to the farm he had inherited in Scotland. Playfair credits Hutton with introducing good tillage to Scotland where it had since "made more rapid advances than in any other part of Great Brittain."

Hutton lived a peaceful rural life for fourteen years, and he continued to observe mineralogy and geology. Most importantly, Hutton took careful notice of erosion and the rates at which water and wind carried away his soils. When he built a sandstone wall to capture his disappearing soil, he noticed that even the sandstone began to slowly disintegrate into sand grains and mud, and these too would quietly disappear. These types of observations were foundational for Hutton's *Theory of the Earth*. Early on, he discovered that all surfaces on Earth were subject to constant change by erosional forces, and he saw that many of the rocks themselves were made up of those sand grains he had watched wash downstream toward the ocean. James Hutton began to conceive of Earth as a force of change that began with the destruction of land. Its formations resulted from a series of slow-moving cycles, not a short, linear history exemplified by Werner's universal flood.

In direct contrast with Abraham Gottlob Werner's Catastrophist understanding of geology, Hutton's became known as Uniformitarian. His governing philosophy was *causam naturalem et assiduam quaerimus, non raram et foruitam*, or to seek the natural and permanent cause, not the rare and accidental. He was not interested in explaining original creation, for which he could find no physical evidence. Hutton explained his methods in *System of the Earth*, an abstract of his presentation to the Royal Society of Edinburgh in 1785:

> As it is not in human record, but in natural history, that we are to look for the means of ascertaining what has already been, it is here proposed to examine the appearances of the earth, in order to be informed of operations which have been transacted in time past. It is thus that, from principles of natural philosophy, we may arrive at some knowledge of order and system in the oeconomy of this globe, and may form a rational opinion with regard to the course of nature, or to events which are in time to happen.

Hutton did not believe that the bible, a human record, should be a starting place to understand natural history. He formed his theories by looking to the land, and he found no record of human fossils, but he did find ancient "inferior species" of animals. He did not believe that humans were created at the beginning of time. Therefore, human records were inadequate means to understand all of geologic history. The only way that he could learn about the past was by studying rocks and assuming that the present was the key to the past—that the same laws and processes that operate in the universe have always operated in the universe, and can be assumed to continue to operate in the future—the basic tenet of Uniformitarianism. Hutton's interpretations of natural phenomena were shaped by

this belief in slow, constant change that was incompatible with the Christian timescale and associated catastrophic theories of the Earth.

However, Hutton was not an atheist; he did not abandon faith in a benevolent force, and he still believed in divine purpose for human beings. Hutton came to believe in a Natural Law. This "wise", "consistent" "system" had, at some unknowable time, been set in motion, and produced a beautiful, constantly changing world. Nature, or perhaps the force behind her, was purposeful, not strictly mechanical. In his 1785 abstract, he compared Nature to an organism that operated in order to sustain life and produce beauty. His personification lent agency to a force of nature

> Nature does not destroy one continent from having wearied of a subject which had given pleasure, or changed her purposes, whether for a better or a worse; neither does She erect a continent of land among the clouds, to show her power, or to amaze the vulgar man: Nature has contrived the productions of vegetable bodies, and the sustenance of animal life, to depend upon the gradual but sure destruction of a continent…. But with such economy of this world, that the destruction of one continent is not brought about without the renovation of the earth in the production of another; and the animal and vegetable bodies, for which the [continents]… [are] leveled…, are among the means employed in those operations, as well as the sustenance of those living beings is the proper end in view.

Plants and animals both contributed to and benefitted from this system of change. Nature's cycles were not violent toward life, nor were they destructive acts to evoke fear in human beings. Life was dependent on this dynamic system, and change would continue infinitely in order to serve its divine purpose. Destruction of land was a necessary step for renewal on which life depended.

As a true natural philosopher, Hutton's philosophical understanding of the world were inextricably linked to his scientific understanding of nature. His experiences led him to the belief that human beings had a unique purpose—to experience intellectual pleasure in scientific pursuit and to feel the happiness that results from observing Earth's beauty through the senses. In *Theory of the Earth* (1788), he explains,

> The globe of this earth is evidently made for man. He alone, of all the beings which have life upon this body, enjoys the whole and every part; he alone is capable of knowing the nature of this world, which he thus possesses in virtue of his proper right; and he alone can make the knowledge of this system a source of pleasure and the means of happiness (Hutton 1788, 216).

At first it may seem as though Hutton expressed a belief in some sort of divine anthropocentric entitlement, but this interpretation is seemingly contradictory to Hutton's understanding of the depth of geologic time and the comparatively small history of human beings. Perhaps the key to Hutton's intent when he says the earth is "evidently made for man" can be found by understanding what he means by "evidently." This qualification turns out to be consistent with his understanding of time because Earth could not have been "evidently made" without something, or someone, to make it evident.

As the sole creature capable of making evident the process of nature, Hutton believed that humans had the sole capacity to "enjoy" every part of nature, and to relate each piece to their understanding of the "whole." Earth was "made for" humans by virtue of their ability to understand themselves as a part of and player on the planet, and also because they strive to make evident exactly what the being of Nature really is. No other living creature could do this. The functional definition of a

human being within the "system" of the natural world is one who "makes evident" this nature, and as things could only be made evident on a human being's terms, it is his or her "proper right" to fulfill the role of acting as a self-awareness of the natural system. For Hutton, the greatest joy that he could experience arose from being a natural philosopher and fulfilling his proper role in Nature.

> Man alone, of all the animated beings which enjoy the benefits of this earth, employs the knowledge which he there receives, in leading him to judge of the intention of things, as well as of the means by which they are brought about; and he alone is thus made to enjoy, in contemplation as well as sensual pleasure, all the good that may be observed in the constitution of this world (Hutton 1788, 217).

Hutton saw intentionality in the natural world, and he believed it was the human's role to "judge," or to find meaning, as well as to understand the origins of natural creation. In this occupation, human beings enjoy both the sensual beauty of nature and relish in its all-pervasive benevolence.

In 1785, Hutton presented his philosophical and scientific understanding of Earth to the Royal Society of Edinburgh. His views on the age and formation of Earth were controversial if not heretical, and he had never before expressed his theory to an audience. His abstract from the lecture, *System of the Earth,* published the same year, is the only complete record of the content of his presentation that day, and begins with the following thesis statement:

> The purpose of this Dissertation is to form some estimate with regard to the time the globe of this Earth has existed, as a world maintaining plants and animals; to reason with regard to the changes which the earth has undergone; and to see how far an end or termination to this system of things may be perceived, from the consideration of that which has already come to pass.

That day, Hutton communicated to his audience a system that was remarkably consistent with, though simpler than, the modern rock cycle. He posited to his peers that erosion, a slow process that all could witness, was one part of the Earth's great cycle. This system began with the slow journey of tiny sediments down slope to their ultimate grave in ocean basins. There, they accumulated in horizontal beds and were compacted by overlying pressure as well as solidified by "subterranean heat." This source of heat energy ultimately lifted these beds up out of the water, to form continents and their mountains. This continuous cycle of erosion, deposition, and uplift necessitated that the sedimentary rocks of the modern continents must have originated from the sediments of a previous world. Similarly, their land was continually eroding into sand grains that traveled slowly to the ocean floor, and would ultimately become rock on the ocean floor, then spring up to form the next world.

Having presented his system, which explained much of Earth's geological phenomena, as well as its religious implications, James Hutton readdressed the question of time, the central message of his presentation. He explained that in order to know how slowly the system operated, he would have to be able to measure the rate at which a mountain decayed into a pile of sand on the ocean floor. It is at this point that Hutton admits defeat, and famously concludes:

> But, as there is not in human observation proper means for measuring the waste of land upon the globe, it is hence inferred, that we cannot estimate the duration of what we see at present, nor calculate the period at which it had begun; so that, with respect to human observation…
> …The result, therefore, of our present enquiry is, that we find no vestige of a beginning,--no prospect of an end (Hutton 1785, 28; Hutton 1787, 304).

Hutton did not, as he is often misread, believe the world infinite. Rather, he maintained that it was an unsolvable mystery by human observation. However, regardless of his failure to estimate an age of Earth, it was clear that Hutton's understanding of Earth history had little to do with biblical creation stories.

Scientifically, Hutton's peers criticized the lack of concrete evidence in his largely theoretical presentation. He did not adequately support the extremely controversial vision of a cyclical system of Earth, the constant motion that relied on a deep heat source. His cyclical theory laid in direct opposition to the widely accepted view of a more static geology, punctuated by few, large-scale events. Before publishing *Theory of the Earth* in 1788, he took a variety of field trips with his peers in order to find places that would unquestionably demonstrate the cyclical system. The most famous of these expeditions resulted in the discovery of an unconformity at Siccar Point.

On that pleasant day, James Hutton sailed a small boat with fellow scientists and friends, John Playfair and James Hall, as well as a small crew. They explored the western coast of Scotland, looking for outcrops that would support Hutton's theory. John Playfair described Hutton as a passionate and charismatic teacher and adept philosopher. In his biography of Hutton, Playfair described his consistent state of joy. However, nothing gave him more pleasure than a discovery in the field that would support his theory. When Siccar Point came into view, Hutton must have become overcome with emotion, gesturing to the shore, as the craft pulled up to the rocky shoreline. In his biography, Playfair recalled,

> The sight of objects which verified at once so many important conclusions in his system, filled him with delight, and as his feelings, on such occasions, were always so strongly expressed, the guides who accompanied him were convinced that it must be nothing less than the discovery of a vein of silver or gold, that could call forth such strong marks of joy and exaltation.

Hutton, about twice the age of Hall, would have jumped off board before the boat had stopped. He probably landed in the shallows before scrambling up the slippery, exposed rocks. Once on dry land, he would have stood, grinning wildly, eager to share the significance of this angular unconformity, a geologic structure whose formation relies on vast passages of time.

Figure 1: Angular unconformity on the eastern cliff of Siccar Point. Red sandstone (345 million years old) directly overlies greywacke (425 million years old). The erosional surface represents 80 million years of time between the two units. From the perspective of Hutton, approaching from the ocean in the background, the underlying strata would appear vertical, cut off by overlying horizontal beds.

For Hutton, this angular unconformity was the perfect evidence of cyclical processes and vast amounts of time. In this wildly layered outcrop, Hutton saw many worlds. His interpretation explained how the underlying greywacke was an ancient land that formed on the seafloor, and was uplifted with such force that that the beds, which formed horizontally, could be seen shooting vertically into the air. With time, this land too had been leveled by erosion. As another continent sprung up, the ocean covered this rock. This new world decayed, and sediments began to settle on top of the former one. As these new sediments piled up horizontally, they were cemented together by pressure and heat, ultimately springing back up into the air, and exposing the unconformity, a structure with rocks of vastly different ages, in contact with one another.

John Playfair listened intently as Hutton gesticulated wildly, shouting the unfathomable story over the sound of crashing waves. After seeing it with his own eyes, Playfair never again doubted the validity of Hutton's cyclical conception of Earth. As Hutton's words sunk in, he was overcome with the vastness of time the system required:

> On us who saw these phenomena for the first time, the impression made will not easily be forgotten…. The mind seemed to grow giddy by looking so far into the abyss of time; and while we listened with earnestness and admiration to the philosopher who was now unfolding to us the order and series of these wonderful events, we became sensible how much further reason may sometimes go than imagination can venture to follow (Playfair 1790, 73).

Playfair was the first to articulate the paradox of deep time. In Hutton's vision of the Earth, geologic history was so immense that human beings could never be able to determine or conceive of its age. From the human perspective, time seemed to

stretch forward and backward infinitely. Though today the Earth has been calculated at 4.54 billion years old, in a sense, Hutton's most famous words, "No prospect of a beginning," hold true. Playfair's paradox is exactly right. Radioactive isotopes have given us the age of the earth, but we are no closer to conceptually understanding one million years, let alone 4.54 billion.

At places like Siccar Point, places that drip with the awesome truth of time, we have a tendency to scramble up the rocks in order touch the contact between the two worlds. It feels important, almost holy to stand before these exposures and place our hands on the wall, to contemplate the lost time, the pieces that have eroded away, and are gone forever, incorporated into some other world. Unprompted, we are overcome by the temporal implications in the rocks. Geologic time becomes real. Though our imagination cannot conceive of their lifespan, cannot process this "abyss of time," our fingers can feel these rocks. We can physically commune with these ancient lands. Our minds open up to a new dimension of time denied to us in our daily lives.

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Occasionally I remind myself of the John Day Fossil Beds, the place where I discovered time, and I revisit Goose Rock in my imagination. I can close my eyes and reconstruct the landscape. As I do, sometimes the dry scrublands transform into a tropical beach.

As I walk along the wetted perimeter, the shallow, warm sea washes over my feet. There are coiled shells everywhere. They glisten, refracting rainbows as the hot sun flashes across their iridescent spirals. I pick one up. It is as big as my own head. It is not the shell of a giant snail, but of an ammonite, an extinct cousin of the squid. As I look to the ocean, I can see their shells flash beneath the waves as they propel themselves forth, looking for something to eat.

Something else catches my eye offshore. A large creature surfaces to breathe. It looks distinctly like a porpoise, even leaping out of the water and flashing its tail upon reentry. This is no dolphin or whale. It is not even closely related. It is an icthyosaur, a swimming reptile, and it held this niche for 150 million years until a changing climate caused oxygen to become depleted in the ocean, and the world turned over, giving way to the next generation of sea creatures, where ultimately, the whales would take its place.

My wanderings lead me to an empty channel on the delta, filled with rounded stones and lined with unfamiliar moss. From the tall mountains to the east, a wide, powerful river feeds into the sea. Its channels split, stretching out like birds' feet as the water reaches the gently sloping coast. For now, the water has chosen to follow a shorter channel ahead of me, where it rushes into the sea, carrying with it rounded pieces of the ancient ranges from which it came. I reach down to pick up a green cobble from the dry riverbed. It is smooth and feels like a cool goose egg in my hand. I smile, knowing perhaps, if I am really lucky, I might be able to find this same stone back in a cliff face in the Holocene.

CHAPTER TWO

One Day to Fly

> A vast and shadowy history loomed in the rocks. It threatened to be a history in which man's entire destiny would lose the significance he had always attached to it.
>
> Loren Eiseley, *The Firmament of Time* 1960

The sounds of the rainforest gradually increased in volume as evening fell. Howler monkeys hooted and insects rubbed their wings to add their chirping to the beautiful dissonance of dusk. As daylight began to fade, I boarded a motorboat with my older sister and parents while white-winged mayflies began to dance around us.

The boat driver, a tall Belizean Creole man, turned the ignition, starting the motor at the back of the boat and took his place behind a large wooden steering wheel. The four of us sat on the rows of benches in front of him, their whitewash peeling, undoubtedly from the thick humidity. It is a tough climate. Nothing lasts long in this place.

The mayflies seemed to multiply, and soon they swarmed about our boat, flitting over the river, coming together in couples in the air and on the water. I

twitched as they flew past me, trying to stay out of their way. Their bodies were pale and translucent. Their clear wings, glistering like a gossamer net, whirred gently by my ears. Ephemeroptera, the order of the mayflies, was born into existence in the late Carboniferous period, 310 million years ago when their cousins, the dragonflies had two and a half foot wingspans. Insects dominated the swamplands. Amphibians flourished and later crawled out of the water, evolving into to reptiles and becoming the first creatures to lay eggs outside of the water.

"We will turn this on in a few minutes." Our guide spoke as he rested his hand on the spotlight beside him. We accelerated, and the flies struck my face repeatedly. I covered my mouth so I could breathe without inhaling them. The moon and stars were our only source of light as we rode through the night.

"Ready?" He asked us without explaining what we should prepare for. We were still in motion as he switched on the spotlight and slowed the boat. The beam of light was clouded with white streaks—hundreds of thousands of mayflies. It was like looking through a windshield while driving through a snowstorm at night, those blurry specks, swarming the light.

After a matter of seconds, he turned off the spotlight. We continued on in silence. As the minutes passed, the flies ceased to bother me. Soon, I no longer noticed them at all. I wondered if had it just been the light that attracted them to the boat.

"Ready?" He asked again. I groaned audibly in harmony with my sister beside me. He paid us no mind and switched it on once more. This time, there were no mayflies filling the tube of light. I waited, but they failed to appear.

"Hatch, mate, and die." He said. "One day to fly."

Ephemero-ptera translates to short lived-wing. The larval stage ends after about a year when it crawls from under the mud and rises up to the freshwater surface, transforming into an adult as it cracks out of its exoskeleton into an adult form with wings. Adult mayflies live anywhere from minutes to two days. Their adult form cannot eat. They spend their last reserves of energy mating, and then fall, as the mothers struggle to place their eggs safely in the water.

For the rest of the ride, the light stayed on, as our guide pointed out nocturnal creatures in trees and along the shore. But anytime his swinging spotlight caught the water, we remembered the mayflies. There they lay, floating, dead, dying, covering the surface of the river with their exhausted white bodies as their eggs sunk quietly into the mud below.

One day to fly—the words come back to me now and again. They were so numerous, and then there were naught. A whole lifetime in a human day. At twelve years old, I experienced a painful awakening to mortality. It was tragic. Did they know the sun rises more than once? What would I never live to see?

~ -- ~ -- ~

Hutton never had to question his belief in a benevolent natural force because he had never heard of extinction. In the nineteenth century, as William "Strata" Smith began to map the geologic units of England, he saw that different types of

creatures were preserved in different units, and as he began to understand the stratigraphy of England, he discovered that he could use fossils as a tool to correlate units in time. If a formation had similar fossils to another, they must have formed around the same time period. This Principle of Faunal Succession is still used by geologists today. As geologists began to take further note of fossils, it became apparent that older rocks tended to have less complex creatures, while newer rocks bore fossils of more complex and modern species. The ideas of evolution began to take hold. However, some species appeared unique, and had never been seen alive. In 1831, Georges Cuvier was the first to interpret extinction when he found fossilized bones of an ancient elephant species unlike any seen living on Earth. Hutton's argument for a wise, consistent system of nature began to unravel. Why would Nature create a species and then haphazardly reject her own creation? Would Hutton's perspective have transformed if he had lived just thirty additional years?

And how would Hutton respond to Darwin's idea of natural selection? Charles Darwin's *Origin of Species* argued for evolution, the descent of all species, including humans, from common ancestors. Evolution had been debated for almost a century, but after Darwin's *Origin*, the concept was essentially accepted overnight. However, the causal mechanism, natural selection, was more difficult to swallow. In Darwin's theory, species acquired traits and evolved by way of a random happenstance, variation. If the trait happened to be useful for finding food or sex, it was naturally selected for and passed on to offspring. Though Darwin did not know how to explain the reason for variation, he was sure that the driver of evolution had nothing to do with intentionality, wisdom, or consistency. Species evolved because

of random variations and chance environmental circumstances that selected for them. Charles Darwin accepted that in evolution there is no direction and no end. Therefore, a believer in Darwinism believes there is not one special species with an immortal soul, God-given purpose, or afterlife.

In his memoir, which he never intended to publish, Darwin reflected on his spiritual life and how, almost against his will, his orthodox beliefs in Christianity faded to agnosticism. His scientific ideas were simply incompatible with his conception of God. For Darwin, natural selection precluded the belief in both a divine purpose of life itself and the belief that humans were meaningful as the chosen creatures of God. Though Darwin had started out as a pious young man, even quoting bible verses while on the *Beagle*, but as time went on, his faith began to dissolve. He wrote regretfully about this loss in faith, "Thus, disbelief crept over me at a very slow rate, but was at last complete." Whereas Hutton found meaning in his connection to the divine through his own natural purpose, Darwin became disconnected, self-aware creature living in a materialistic world. While for Hutton, meaning came from fulfilling his given purpose to study and enjoy nature, Darwin was left purposeless and without meaning.

Loren Eiseley couldn't have known that a fossilized skull would be buried in the strata as he rode his horse through the "sunlit, timeless prairie." The prairie evoked the present moment, the current world, without hint of its past. It was not until he he happened upon the "Slit," a slot canyon that had been carved deep into the sandstone by a series desert flash floods, that he could look deep into the past.

He could not help himself. The crevice was barely the width of his body, and he slid down inside of it until "the sky became a narrow slit of distant blue and the sandstone was cool to [his] hands on either side." The Slit seemed somehow menacing, "like an open grave… for over [him] the sky seemed already as far off as some distant century I would never see." As he dropped down through the canyon, he left the modern world behind and descended into the past.

To Eiseley's estimation, the narrow channel cut through ten million years worth of sandstone layers, and at its bottom, he came upon a fossilized skull. An anthropologist and natural historian, Eiseley had hoped to find some sort of bone from an ancient vertebrate, but what he found took him by complete surprise, as did the insight that followed from such an experience.

> The skull lay tilted in such a manner that it stared, sightless, up at me as though I, too, was already caught a few feet above him in the strata and, in my turn, were staring upward at that strip of sky which the ages were carrying further away from me beneath the tumbling debris of falling mountains (Eiseley, *The Immense Journey,* 5).

Eiseley experienced a profound impression that he was already a fossil, extinct and buried in the strata as millions of years of sediment continued to pile up on top of him, as the sky became more and most distant above him. Eiseley anticipated and, in a sense, experienced the death of himself and of his species, the extinction of humanity. What would he, like the extinct mammal in the rock, never see as the sand grains of new worlds pushed him farther below, away from the sky? What species would outlast the human beings—would adapt and radiate out to fill our niche?

Loren Eiseley remained in the Slit, and as he chiseled away at the fossilized skull, he acknowledged the imminent extinction of humanity, and was not

discouraged. He examined his agile fingers and pondered their journey from fin to reptile foot to mammal paw to opposable thumbs. This comforted him. He accepted his temporal limitations as a necessary part of the process of evolution. He was satisfied that he could play a role as a link in an evolutionary chain. Darwin's discovery of purposelessness did not dismay him, "Perhaps there is no meaning in it at all… save that of journey itself, so far as men can see…. Do not look for a purpose, Think of the way we came and be a little proud." Loren Eiseley avoided loss of meaning by finding connection to all living things as a piece of an evolutionary legacy and the great experiment of life. Though he recognized his limitations and inability to conceive of a greater purpose, he did not rule it out; he just dismissed it as irrelevant. He was in awe of the random chain of causes and effects that led to the beautiful world he saw around him, and he was proud to be apart of it. Rather than eliminating faith in the indescribable wonder of the natural world, science revealed more mystery to Eiseley. There were some things that he believed humans were simply unable to conceive of. Geologic time stretches wide from the beginning of Earth in the unseen future, but humans can only really understand lengths of time they experience. He suggested that in the elaborate symmetry of a snowflake, whose aesthetics serve no utilitarian function, there is a clue to the mystery of organization, of the principle, which caused the first spark of life. This is one mystery that he hoped and believed humans would never be able to fully understand.

CHAPTER THREE

Nannofossils

> If you free yourself from he conventional reaction to a quantity like a million years, you free yourself a bit from the boundaries of human time. And then in a way you do not live at all, but in another way you live forever"
>
> Anonymous geologist, John McPhee's *Basin and Range*

Occasionally in my petrology class, Professor Kirsten Nicolaysen would hold up a sparkling rock, identify it, and tell the class that it was over one billion years old. I started to notice how she would wait a beat after a number like this. Her grey eyes would search the room for some sign of recognition, and often, almost casually, she would repeat herself.

"One billion years old."

This was probably the only time that Kirsten's lectures slowed down. Her classes were a passionate performance, dancing from the projector to the chalk board, over to the periodic table, back and forth from the rock sample room, and over to the hot plate where, "Damn! The demonstration failed again!"

Her bias toward experiential learning was obvious. She turned that ancient rock over in her hands as she lectured about its formation, and as she jumped over to cue the next slide, she quickly rebounded, deciding to pass the sample around.

"I'm going to pass this around in case you like to feel things too," she said as she laughed, and she plunked it on the lab table in front of me.

I once asked Kirsten after class how she conveys deep time, a concept that is so difficult to articulate, but so clearly meaningful for her.

"It's only really possible outdoors, and even there, only one or two students will get it. I can tell by their eyes. If even one student understands the meaning of what they are seeing, it is worth it." It took Kirsten nine years of undergraduate and graduate geology before she felt her first visceral connection to geologic time, and so she understands that the meaning of deep time cannot be taught, it has to rise through an experience.

At first you wouldn't know that Kirsten spent a lot of time avoiding conversations about time. Her parents were biblical literalists, and she had been raised to believe in the absolute truth of the bible. However, from a young age, she was more interested in running wild on the rocks of her Wyoming family ranch and figuring things out for herself. When she and her brother heard rumors that there might be dinosaur bones on their property, they began to dig for fossils and anything else they could find. They were paleontologists interpreting the ancient landscape. She never got a straight answer from the church on fossils, and she began to notice a lot of contradictions in their explanation of scientific phenomena.

As a young adult, she began to distance herself from the church. She couldn't believe in anything that couldn't be verified by her own experience. "I guess I am genetically programmed to be a scientist," she said. By high school, she had heard of the geologic eras and epochs, but she did not yet confront the contradictions with her family's beliefs. Even as an undergraduate at University of Wyoming, she elected not to take earth history or paleontology, and focused on hard rocks and their processes, where time wasn't a fundamental concern. Unlike piles of oceanic sediments, which take years to accumulate, volcanic eruptions are punctuated, catastrophic events that can produce a thick layer of ash from one violent explosion. In graduate school, Kirsten studied the composition of these ash deposits and lava flows to determine trace amounts of certain chemical elements and isotopes that were diagnostic for certain processes or origins. These methods gained legitimacy as she worked with them and saw consistencies between her observations in the field and results in the lab. By the time she was working toward her PhD at MIT, she was using these same isotopes to date metamorphic rocks to billions of years in origin. There was no doubt in her mind that the Earth was old and its processes were usually slow.

The day after her 29th birthday, Kirsten joined a scientific crew for a sixty-day research expedition to drill cores in the Kerguelen Plateau, a mostly submerged mini continent in the southern Indian Ocean. Aboard the Joides *RESOLUTION*, she performed research on the geochronology of oceanic crust by sampling drill cores that reached from sediments down into the shallow crust of Kerguelen.

Before hitting the hard stuff, technicians drilled through 526 meters of calcareous ooze and chalk, made of nannofossils less than one millimeter in diameter, which have been collecting on the submerged Kerguelen Plateau since the age of the dinosaurs. As a paleobiologist, Woody Wise studied ancient life via the fossil record and received cylindrical cores from the drill. The crew carried 330 five-foot-long cores into the paleobiology lab where the scientists examined them with a scanning electron microscope to identify the creatures and date the sediments using the Principle of Faunal Succession. All but three of these 330 cores consisted entirely of nannofossils.

Kirsten watched the drill come up from the depths and helped carry core after core of mud, calcareous ooze and consolidated chalk into the lab. At drill site 1135, rests an almost perfectly continuous pile of 130 million years of the evolutionary history of phytoplankton, slowly accumulated in a stack of 526 meters of sediment. As Kirsten smeared the white mud on glass slides for Woody's SEM, she began to carefully keep track of time as they analyzed the cores from the bottom of the pile to the top.

At the very bottom, 526 meters, the depth of six football fields, the cores brought up light greenish chalk. These nanoscopic algae lived in the Cretaceous, in the age of the reptiles, 130 million years ago.

At 450 meters, the distance from the sidewalk to the tip of the Empire State Building, were the white chalky sediments of algae that drifted down through the ocean 100 million years ago, when most of Oregon was a tropical shallow sea and a

swiftly flowing river carried the cobbles of Goose Rock from ancient Idaho to the Oregon coastal delta.

The nannoscopic plants in the core 325 meters from the top, the height of the Eiffel Tower, lived 80 million years ago, as primates diverged from mammals and took to the trees.

Progress was slow, but Kirsten continued to track the time. She knew that in less than a hundred meters, they could find evidence of the meteor that killed the dinosaurs.

She was right. 261 meters below the surface, there was a distinct narrow grey clay layer with a dark line running through it. She happened to step into the lab just as the technicians split the core in half. The Cretaceous/Tertiary extinction event, 66 million years ago, resulted in the extinction of 75% of plants and animals likely due to a massive extraterrestrial impact. Life on all continents was affected, and there was a major turnover of life in the oceans, too. The ammonites, swimming reptiles, dinosaurs, and a huge number of plant species were gone forever, thanks to this random catastrophic event. It was only due to good fortune and the right set of genetic characteristics or perhaps pure happenstance that some species, such as mammals, survived, and began to repopulate the world. One such animal, the tupaia, is the common ancestor of all primates. It was an insect-eating mammal, about the size of a squirrel that lived in the high branches of tropical trees.

Figure 2: *Tupaia minor*, the pygmy treeshrew, a modern primate that is analogous to one of the most primitive placental creatures of the Paleozoic and the common ancestor of all primates.

At about 90 meters beneath the surface of the pile of nannofossils-- the Statue of Liberty from base to torch-- unconsolidated ooze lies above chalk. This section correlates with 15-20 million years ago, when the evolution of tupaias had branched off along several lines since the Cretaceous, producing lemuroids and anthropoids, the ancestors of apes, baboons, tree monkeys, and human beings.

Eight meters, or 26 feet below the surface, are nannofossils that produced oxygen 2 million years ago, during the Stone Age when the first true humans, genus *Homo,* lived with families, sought shelter in caves, and utilized fire, tools, and weapons.

One meter deep, Woody Wise found nanofossils from 250,000 years ago. Human beings had modern anatomy and began to develop language. This is during the Pleistocene, the ice age epoch.

Fifteen centimeters, half a foot deep, were fossils formed 5,000 years ago when humans began to use metal.

One centimeter down, it was 1726, when James Hutton was born.

My whole life, 22 years, turns out to be analogous to the size of a nannofossil, less than 1 millimeter tall.

Five hundred twenty-six meters of chalk and ooze contained 130 million years of geologic time. As she watched those 330 cores, all made of plankton, pulled out of the deep ocean, Kirsten experienced a moment of awe. For the first time in her life, she saw time and could understand her own lifetime in relation. She still gets cold shivers when she thinks about that moment.

This pile recorded 130 million years, a sizable chunk of time, but just 3% of Earth history in its entirety. If all of earth history were preserved in such a pile, it would be 1,127 miles high, as far as the distance from Canada to the Mexico. To be less than a millimeter along a journey over a thousand miles long is not that easy to stomach. The nannofossil whose size represents the duration of my life requires an electron microscope to see.

Though Kirsten Nicolaysen does not hold faith in an intentional guiding force, she continues to think that life would be simpler if she did. She would feel meaning by fulfilling God-given purposes, she would have answers to life's difficult questions, she would would have the faith that her prayers would heard and might be answered, and she could reassure her children that they would always be together in heaven. Regardless of her agnostic position and scientific mind, she continues to

believe in the importance of "the spiritual journey." For now, she can comfort in biogeochemical cycles, the idea that chemical elements constantly recycle and reorganize into organic and inorganic forms:

> "I personally find the idea of biogeochemical cycles very reassuring and very comforting. That I personally very much like the idea of cremation, of letting ones chemical elements free to go nourish or be part of some other aspect in the world…I don't think there needs to be any transmission of the soul. If its just the physical material, that's okay."

Whereas Darwin lost meaning when nature (and humans in tandem) lost divine *purpose*, she has found meaning in *connection*, in participating in the physical cycle of all things.

Evolution reveals a tangled, twisting, and fraying string of life over time, a lineage along which things that have gone can never return. However, we can take comfort in the observation of cycles and patterns. We are not one distinct piece of an evolutionary legacy; we are a transformation of the original ancestor. All things on Earth were originally born of the stars, made up of elements that have been different pieces of the earth, whether mineral, air, plant, animal, tree, fungus, virus, and that will be something else when we die. Biogeochemical cycles are eternal, though individuals are finite.

CHAPTER FOUR

Two Scales of Time

> A believer in Unity, a seer of Unity, I yet behold two… Cannot I conceive the universe without contradiction?
>
> Ralph Waldo Emerson

I got my first glimpse of the overwhelming depth of time in the John Day country in Oregon. My classmates and I dug up extinct, fossilized leaves preserved in mudstone in Fossil. We squinted at mangled chunks of the green inner earth that found itself smashed up on land near Baker City. At Mt. Vernon, we stood beneath massive cliffs of white ash, a violent deposit of a super-volcano that was so old we could not find the crater. Until this particular field trip, the geologic ages had run together in my head, meaningless. Now, in the Paleo Lands of Oregon, I finally began to have moments of clarity. As the epochs and eons began to sort themselves out and stretch back through my imagination, a shift occurred in the way I saw the world.

On the last night of our four-day field trip, Mattie Griswold and I huddled together in a sort of fort. It was not unlike the ones I would construct in my

childhood, where I'd crouch inside with my knees drawn up to my chest, but instead of blankets slung over furniture, the indigo tapestry draped over the gorge's dark cliffs. The sky seemed to curve beyond them, as if neatly tucked under the basalt from the outside.

She sat next to me, but we did not speak. We simply stared up at points of light escaping through the fibers of the deep blue cloth, our minds reeling with the new truth of time.

The dark crags dwarfed the hill on which we sat. Below us, the moon illuminated a wide river cutting through a narrow valley. A campfire flickered by the riverbank where our classmates murmured ghost stories and cracked open aluminum cans.

Up on the hilltop, all was still. We sat mesmerized with minds racing and lips unmoving. Mattie almost never breaks a silence. She sat comfortably in the quiet with her thoughts. But I was bursting to speak, to make sense of this seemingly life changing weekend, to work it out aloud.

"If no one had ever told me, I'd swear the sky was two-dimensional. Do you know what I mean? ... Look Griz, it's an optical illusion. I can see just us, just this place. The sky seems to curve down behind this cliff, the whole world is this small river valley."

The faraway stars limited my perspective, revealing a shallow sky, a curved surface with lights sprinkled just so for my own enjoyment. I wished I could believe my eyes. Perhaps then I could conceive of Earth and my own size in comparison.

As Griz turned toward me, her long pale braid slipped over her shoulder. In the moonlight the birthmark was barely visible on her right cheek. She understood. Her eyes squinted as she reflected what I was trying to say, on what we would quietly wrestle with for the rest of our college years. She turned back up to the sky, inhaled deeply, and shrugged, apologetically.

"We're so small."

As I began to look at the world with a geologist's lens, the time scale was suddenly present every time I saw an outcrop, boulder, soil horizon, or river channel. I no longer saw rocks; I saw time, power, process, cycling and recycling. Seemingly unprompted, I was overcome by the temporal implications of what I read in the rocks.

Deep time began to linger, and as I walked inside, trying to go through the motions of my daily life, the timescale geology and the days that measured my own began to clash. They felt incompatible, immiscible, impossible to reconcile. I was at what some call the most formative and important time in a young person's life, the four short college years, and at times I found myself faced with an overwhelming feeling of apathy and confusion. The decisions that had once seemed of utmost importance—*what classes would I take to prepare for my future? What causes should I spend my time fighting for? What types of people should I surround myself with?*—now felt irrelevant and unimportant. In the context of geologic time, nothing I did seemed to matter whatsoever. The assurances I had been bathed in as a youth—*You are special. You are going to make a difference. You are going to change the world*—

words I had long relied on when anxiety overtook me now these words rang false. My life seemed quite obviously insignificant; my existence was certainly a random, meaningless occurrence. As the Paleo Lands stayed with me in my daily life, I began to wonder if it was possible to make any difference in the grand scheme of things.

I functioned by compartmentalizing the timescales. I suppressed deep time, and focused on the day-to-day. In human time, my life was meaningful. My relationships were important. My schoolwork was relevant. I appreciated human creativity—music, art, poetry—these things seemed to resound with meaning. As I focused on the human, the geologic faded into the background.

But out the in field, my focus would switch. Amongst outcrops and landforms, I lived with the geologic timescale, the *true* sense of time. Out there, I became invisible as I observed landscapes.

The summer following that sophomore year at Whitman, I accepted a temporary position at the United States Geological Survey. My team traveled up and down the Cascade Range to study chemical clues that bubbled up through hot springs on the flanks of the active volcanoes of California, Oregon, and Washington. One early morning, I arrived at Mount Rainier. It was August, but above the visitors' center and parking lot, the terrain was completely snow covered except for the sheerest faces of the mighty volcano.

I stood on pavement plastered at 5,000 feet above sea level and stared down the massive black edifice. It rose steeply to a 14,410-foot snowcapped summit. After arranging sample bottles and measuring instruments in my backpack, four of

us stepped onto snow in search of a single spring, a conduit through which chemical signatures rose as hot water and gas from the depths of the volcano.

As I crunched forward, I watched a group of mountaineers advance toward the summit. They treaded confidently, these specks against the stark landscape. Their silent figures moved in synchronized steps along a ridge that led them toward the looming peak of the Cascades' tallest and most deadly volcano.

I paused as a gentle wind shook the pine needles, and I inhaled deeply, savoring that distinct flavor of raw oxygen found in Washington's alpine forests. I checked our GPS position to ensure that we were following the route that lay hidden beneath the snow.

The snow was getting slick as the sun's rays intensified. As I put my map back in my pack, I pulled out my ice ax and slipped on my crampons. I was the only one who had brought them; we hadn't anticipated these conditions in August. I took the lead, chopping steps as we navigated horizontally around a steep ridge. Behind me, my teammates began to express concern for safety. We were not quite half way along our five-mile course through the snow when I fell.

I had been so careful, checking each step with my ax before stepping forth, but as I took one slow step, my foot slipped. I fell on my backpack and began to sled down the snow-covered slope. I accelerated toward one of those steep black outcrops and the talus below. I had precious seconds to react as I slid faster toward exposed boulders far below me. In one motion, I rolled onto my belly, positioned my ice axe against my shoulder and forced it into the snow. The blade slipped, and I continued sliding down the slope. I repeated the self-arrest with greater intensity,

slamming all of my weight through my shoulder as I kicked my cramponed toes deeply into the ice beneath the snow.

Finally, I stopped. Unsure of my next move, I lay immobilized and embraced the mountain that let me fall, wondering again why I study geology, why I study the might of Earth that makes me feel so small. I was one of those specks clinging to the unforgiving flank. But I held on. Why bother? A mountain's timescale leaves no room for meaning, purpose, love, or personal ambition, but I, though a geologist, believed in those things. I, still a geologist, simultaneously subscribed to the human timescale where my experiences, relationships, and thoughts held significance. I was at once humbled and triumphant.

The experience of falling while trying to study Mt. Rainier was a moment that shook my dichotomous perspective. In retrospect, I can see that it was an epiphany of scale. I saw Rainier, powerful, dangerous, ancient, massive, and I saw myself, clumsy, small, curious, awestruck, persistent. Each had its own powers and its own lifecycles.

The scientific concept of deep time and evolution had the potential to strip my life of meaning. My existence had seemed random, irrelevant, and without purpose in the scheme of earth history. And the time scale of the universe was even vaster. On those scales, perhaps my life has been invisible, but by my own measurement, day-by-day, I can discover meaning in beautiful conversations, places, and artistic expression. I can accept and take comfort in the notion that I am a tiny piece of an extraordinarily large and complex system and story, but my own was important as well; it was just a matter of scale.

Why do human beings seek to stretch beyond our own scale? Why are we so curious, so rapt with desire to understand the natural world, so moved by an urge that runs deeper than our desire to exploit its natural resources? Perhaps we sometimes get a feeling that though we cannot live simultaneously in two timescales, there is a distinct connection between them. Perhaps there is an organizing principle; there are patterns that we can continue to find. Maybe we study nature to better understand ourselves. Maybe what we seek is the interconnection of all things.

CHAPTER FIVE

The Journey Itself

> Clearing the mind and sliding in
> to that created space,
> a web of waters streaming over rocks,
> air misty but not raining,
> seeing this land from a boat on a lake
> or a broad slow river,
> coasting by.
>
> Gary Snyder, Endless Streams and Mountains

For the spring break of my senior year, I flew to Denver and drove West over the Rocky Mountains into Utah to see for myself the canyons, mesas, and arches of the Colorado Plateau. My companion, a Colorado native, drove the car so that I could absorb the breathtaking introduction to red rocks and desert flora. As soon as we entered Canyonlands National Park, we pitched our tent and set off from the Elephant Hill trailhead. We climbed stairs that had been chiseled into the slick rock until we stood atop smooth white stone. The landscape radiated out around us, revealing steep canyons, red fins, stone needles, monuments, and snow-capped mountains on the distant horizon.

We followed a narrow trail that wove around these fins and over each ridge to reveal fresh horizons and new canyons below us. As I walked the path among these giant outcrops, I remembered a Chinese landscape scroll, the subject of the first poem in Gary Snyder's cohesive collection of poetry, *Mountains and Rivers without End*. His words trace a trail as it navigates a mountainous landscape, which for a time follows a stream, then slips behind boulders, disappears into the slopes of distant foothills, passes rugged outcrops, and terminates by a boat dock. In the landscape, the artist has included fenced, wall-less shelters, figures on horseback, fisherman in canoes, and weary hikers amongst the gnarled pines, waterfalls, and menacing crags. Rather than exclude humanity from the idealized landscape in this painting, the figures are just as a part of the place as the boulders or the woody shrubs. I began to imagine that I was one of the tiny painted figures walking in that scroll. If my world too were in black and white, the pink sandstone walls around me could have been the looming karst cliffs. The trees were sparse and twisted like the high mountain pines. As in the painting, the trail I walked would disappear as it dipped into valleys or entered slot canyons through the rock. In these places, I disappeared from the scroll and showed up with the path on the other side.

Leaning into the grade, like a particular traveler I remembered along the inked path, I had this feeling that I was included in the landscape. This made it all the more urgent to understand its geologic story and to absorb the meaning of the place. I tried to name the units. I kept track of my progress through time. As I walked through a narrow slot canyon, I stretched my arms out wide to touch the white sandstone and trace a single waving bed, an event of sand deposition, preserved in

the stone. I felt giddy and childlike as I skipped playfully through the land of canyons, wide-eyed, head swiveling and bobbing, trying to take it all in. I felt at home among these rocks, like I could find some cave and hole up forever.

We had cut it pretty close, having left on an eleven-mile loop in the middle of the afternoon. We returned to camp as sunset fell. Hungry and exhausted, I began to prepare dinner as my friend assembled the gas stove. She discovered it was broken. We could not repair it, and we had no wood for a fire. We did not dare complain, and unpacked the peanut butter, jelly, and bread and silently treated ourselves to sandwiches for dinner and breakfast.

The next morning we set off on a trail that led straight out from the campground along a meadow of bunch grass and shrubs growing in red clay. Ahead of us reined a giant tower, a mass of white sandstone topped by a red fin jutting clear up into the sky. We were eager to climb on top of the smooth edifice and see what lay beyond. I felt slower that day, unprepared by the sugary spreads and empty carbohydrates. The trail led straight up to the white hill at the fin's base. I removed my shoes and my feet padded up the naked rock.

There were many levels in Canyonlands. Our campground sat low upon a layer of shale, and our tent rested on soft brown clay. The base of the fins and monuments were resistant white sandstone, which formed gently sloping, rounded ramps like frisbees. Above their white platform, rose vertical red cliffs and monuments, streaked by a few layers of white. As I climbed the white ramp, I

reached a sharp transition to the next level, red sandstone, which rises sharply into wide, flat towers.

Figure 3: I have climbed over the red ridge between the two monuments, and am walking on white sandstone.

We climbed up to the top of the red ridge between monuments, appreciating their steep faces and wishing we were more adept climbers. Up on this crest, a new canyon spread below us. Following cairns, we dropped back onto the white shelf and walked on a sort of middle ground on the left side of the canyon. Below me was a sheer drop into a floodplain, a valley lower in elevation than the one in which we camped. Here the soil was grey, not red. In this newly revealed landscape, I could see the first tall trees since the Rocky Mountains. Black cottonwoods formed a thick

path through the valley, and between their branches, an entrenched channel was carved through the soft soil.

Figure 4: I am looking down into the canyon. The channel is barely visible on the valley floor below.

In some ways, geology seemed exaggerated and obvious in Canyonlands country. Repetitive and bare, there are myriad examples of sedimentary textures and structures with little vegetation shrouding the rocks. As I looked at the cliffs in front of me, I could see each distinct depositional layer by changes in color, texture and form. The white sandstone seems like the most competent layer. It juts out the farthest from the wall, forming ledges and cap rocks called toadstools for their globular form. The sand was deposited in sweeping layers and sorted by size into distinct beds. The rounding of the rock follows the planes of the beds, ancient dunes.

Sometimes, the beds formed gentle steps, and I climbed down through these wavy layers into the valley below.

Figure 5: Here, wavy sand stone beds form stairs. It was easy the imagine wind or water depositing each horizontal bed of sand.

Half way down the canyon, I encountered a ladder. I dropped deeper into the valley where patches of soil covered rocks. Sparse trees and grasses populated every feasible space. My skyline became only the features on the canyon above me, and I recognized how quickly I could become disoriented down there without the mountains and monuments that made up the horizon I had come to rely on. I was completely dependent on the trail. Losing it would mean losing access to the ladder and any manageable exit from the canyon floor.

Now, on the valley floor, I walked on the path's silty soil and wandered amongst the pinyon pines and Utah juniper toward the Fremont's cottonwoods. Being on a canyon floor was a new perspective. The previous day, our hike cut across the white rocks and over red ridges. We walked beneath towers but always above the canyons, with new views over each ridge that evoked squeals of delight, and always saw a familiar horizon. The second day, however, we explored only one fluvial basin from its highest ridge down into its hidden channel.

As I followed the drainage to the main channel and entered the dry river I had seen from above, I found it exhausting to walk on the dry sand and clay, so I took a slower pace. The red clay walls of the channel were steep and crumbling, with tree roots pushing in through its sides. The water had formed a cleanly cut path in this soft sediment, about four meters wide and well above my head. This narrow passageway further restricted my perspective. The cottonwoods formed my new horizon. I could not even see the canyon I was undoubtedly inside of. My world was constrained to the channel.

From the slick rock, it had looked like a small channel, beautifully cutting cleanly through the canyon, meandering through the valley floor. I had romanticized about how a great downpour might cause a flashflood that would rush down the channel, eventually joining the Green River. Now that I was in it, it felt imposing and enormous. I felt as though I had shrunken in size like Alice after she pops the "Eat Me" pill, finding myself below tree roots in a giant channel, with no view of the large red forms around me.

It was dark and slightly damp in the empty channel. I had no way of seeing where the trail would lead, except to follow the sparse cairns that appeared behind river bends and footprints of previous travelers. It seemed as though I was not the only person who had felt lost in the deep riverbed, as wrong steps formed short, misleading trails out and back in to the main channel.

Cairns and sure footsteps finally guided us out of the dry riverbed and onto the sunny floodplain. I felt relieved to be out of the channel, but was still aware of how far up I had to go to get out of the drainage. It was an intimidating distance. The toadstool topped cliffs and towers looked different now. The rocks seemed to mock me. Smooth red and white spires topped with globular cap rocks looked like a creation of Dr. Seuss, like one of the darker landscapes in *Oh the Places You'll Go,* or perhaps of the Cat in the Hat, himself, with his white crosshatched body and tall red and white hat. I ached to climb out of the canyon, to be again a top the shelf, able to gaze both up and down.

I slept a few scattered minutes that night. I lay shivering in the cold, mind reeling about the insidious nature of the Utah desert. For a girl whose natural education had been in the forests of the Sierra Nevada Mountains and the California coast, danger and wildness had been obvious: crashing waves, sharp rocks, a vast cold ocean; forest fire, bears, turbulent glacial streams. At first glance, the desert was sunny and open, but it too is unforgiving and brutal, deceptively wild. It'll kill you slowly—the cold, thirst, exhaustion, confusion—by way of more covert danger. Utah is a place of extremes, of cold nights after hot days, of bare rock and scattered

green. I felt alienated knowing that only the hardiest could take root there, in the shallow patches of silt left behind on solid rock.

The first day I had relished in being a part of the landscape, a tiny figure on an ink scroll, but the second, I wanted to run away. I found nothing comforting or familiar. I felt no connection. I felt rejected. I wanted to lie in an alpine meadow or sit under a pine tree in the Sierras where I knew I could find running water and huckleberry, see familiar birds and trees, catch trout in cold pools of water. I doubted I could survive in this desert landscape.

I was surely humbled by the desert's covert wildness, by the time so easily read on those naked walls of sweeping sandstone, but I did not find the connection I sought, or the compassion that, according to Gary Snyder, was supposed to follow. That night I hated Canyonlands and I think I would have started the car and taken off, had my companion not been sleeping soundly beside me.

I had hoped that my time in Canyonlands would help me shed individuality and learn about the compassion that arises as a result. The poetic work of Snyder that had been on my mind connects back to its epigram, "The notion of Emptiness engenders Compassion." Emptiness is the loss of individuality by way of understanding the interconnectedness of all things. I thought that an awareness of geologic time could serve as this type of awareness. If it evoked compassion, perhaps teaching geology might inspire peace between people and stewardship in the natural world.

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Gary Snyder's description of the scroll is followed by an imperative to look again at land from a wider perspective:

Step back and gaze again at the land:

it rises and subsides—

ravines and cliffs like waves of blowing leaves—
stamp the foot, walk with it, clap! turn,
the creeks come in, ah!
strained through boulders,
mountains walking on the water,
water ripples every hill.

Snyder beckons the reader to "step back" from the scroll and "gaze at the land," to get a perspective so vast that we can watch Hutton's continents rise and fall. In this state of awareness, we do not only see the changes, we move with Earth, participating in the rhythm of the land. We are not, like I thought in Canyonlands, a part of the land if we are one piece of an aesthetic landscape, like the weary traveler on the mountain path; we are connected to the land if we are a small part of everything. Though our first impression of Earth is a static foundation, our new awareness is of dynamism. Like every living thing on Earth, the land never stays the same. In interacting with every other aspect of the planet, it is subject to the same laws of change and time that we are. Because of the high topography of mountains, clouds form as moist air is forced aloft, and water is born as rain and snow. Though

mountains create the raw materials of rivers, these streams of water carve out the mountains and carry pieces of rock down to the ocean. Everything is interrelated.

On the path, it was *I* who sought connection, and *I* who placed my hands on the rocks as *I* wandered through Canyonlands. *I* desired to fit in to the landscape as *I* walked. Perhaps I should have stayed in one place to meditate until I forgot myself entirely.

Gary Snyder's poetry helps us understand why deep time is at once unsettling and awe-inspiring. This perspective of time results in a feeling of emptiness. Our individual life loses meaning in the context of this vast history. But there is a possibility for a deep connection, too. The last piece of *Mountains and Rivers without End*, is called *Finding Space in the Heart.* The poem recounts a series of visits to one vast saltpan between ranges, a featureless playa in the Great Basin, a destination over the course of the speaker's life. One visit in particular demonstrates the act of entering into emptiness, of losing individuality and finding connection and love:

> …turned the truck onto the playa
> heading for know-not,
> bone-gray dust boiling and featureless,
> let the car coast to a halt
> on the crazed cracked flat hard face where
> winter snow spirals, and summer sun bakes like a kiln.
> Off no where, to be or not be,
>
> all equal, far reaches, no bounds.
> Sound swallowed away,
> no waters, no mountains, no
> bush no grass and
> because no grass
> no shade but your shadow.
> No flatness because no not-flatness.
> No loss, no gain. So—

nothing in the way!
—the ground is the sky
the sky is the ground,
no place between, just

wind-whip breeze,
tent-mouth leeward,
time being here.
We meet heart to heart,
leg hard-twined to leg,
with a kiss that goes to the bone… (Snyder 150-151).

In this poetic excerpt, we can learn how to "step back." The speaker becomes aware of emptiness only when he "head[s] for know-not." Recognizing his lack of agency, he lets go of his desire to control his journey, and allows the car itself to determine where it stops. As he releases his impulse to control, he finds himself in a space where "to be or not be" is the equivalent. His being is boundless; he is both everything and nothing. The space is muted, empty, and absorbs all things but "your shadow." A shadow always reflects the moment. Perhaps it is an adequate metaphor for a human being with the notion of emptiness, a featureless representation of a person that constantly changes as a function of the earth's rotation. An empty space has been created, so nothing is in the way of interconnectedness and compassion. In empty spaces, "time [is] here." The lovers meet without individual preoccupations and connect with the deep compassion of two beings without definite boundaries.

Snyder seeks to convey the Buddhist and Hindu concept of interconnectedness, often symbolized by Indra's infinitely extending net which is connected by jewels, which each reflects the light of all the other jewels. All things on Earth are connected and reflect each other's light. The net itself can never be

seen in its entirety, but the things themselves provide clues to the nature of the net, the essence of all things.

Snyder offers one characteristic of the net, flux:

Walking on walking,
Under foot earth turns

Streams and mountains never stay the same.

This stanza, repeated throughout the text, reminds the reader of the dynamism of all things on earth. Human beings walk on the motion of tectonic plates, and all are spinning with Earth's cycles on its axis and around the sun.

If I had an awareness of emptiness, perhaps my two scales of time would dissolve into one web of connection. Seeing time is one key to being able to move beyond the self. If we are humbled by the vast amounts of time when we see it in the cliffs before us, perhaps as natural philosophers, we can realize meaning and interconnectedness by way of observations of the natural world. Though I only have direct access to my own scale, if I can find patterns in the rocks and remember Indra's net, I can trust that all scales are interconnected. James Hutton could not separate science from philosophy, and I do not fault him for that. There is something inherently provoking about the depth of time and flux of matter that I believe cannot be quantified.

Acknowledgements and Notes:

Introduction

First, it should be noted that John McPhee is credited with the term, "deep time," published in the book, *Basin in Range* in a Pulitzer Prize winning collection called *Annals of a Former World*. I drew great inspiration from McPhee's discussion of deep time on pages 79-91, but deep time is one of the themes that runs through *Annals* as a whole. All of the ideas and thoughts expressed in the introduction are my own thoughts, which have evolved by way of the works of the authors listed below and in the bibliography, as well as interviews with the geology department at Whitman College. Though direct quotations were only taken from Kirsten Nicolaysen, I owe special thanks to Patrick Spencer as well as Robert J. Carson, Kevin Pogue, and Ellen Bishop. Also, thanks to Andrea Dobson of the Astronomy department. In reading this thesis, it may be helpful to refer to a geologic timescale, which can be found on the website of the Geologic Society of America: http://www.geosociety.org/science/timescale/

Chapter One

In my explanation of old-school outcrops, I was influenced by McPhee's explanation of outcrops on pages 23-24 of *Annals of a Former World*.

To ensure accuracy of the geology of the John Day region, I used the wonderfully old United States DOI/USGS's pamphlet, *The geologic setting of the John Day Country,* published in 1969. It is an excellent guide to outcrops in the region by way of the major roads, and provides the legend of John Day himself. I also relied on Orr and Orr's *Geology of Oregon* for the regional geologic history.

For Hutton's quotations, I drew from a facsimile of his original publications in 1785 and 1788, all published together with the facsimile of John Playfair's biographies of Hutton, collected by George White. My understanding of Hutton's natural philosophy mostly refers to his 1785 abstract, but used the quotation from either of his works, published in 1785 and 1788, that best articulate his point, regardless of the publication. Hutton was not known for his readability. Stephen Jay Gould's *Time's Arrow, Time's Cycle* has an interesting argument on the philosophical underpinnings of time for Thomas Burnet, James Hutton, and Charles Lyell. For Biographical information on Hutton and the historical context of Scotland, I drew most heavily on Jack Repeck's *The Man who Found Time* and from Playfair's biography, mentioned above. McPhee's *Basin and Range,* and Loren Eiseley's *Firmament of Time* also have discussions of Hutton. Literary analysis of Hutton is hard to come by, but Tom Furniss' "A Romantic Geology," was helpful and an interesting comparison of Hutton to later Romantic poets.

For the Latin translation, I thank Kathleen Shea.

David Souza granted permission via Wikipedia to copy, distribute, and/or modify his photo of Siccar Point.

Chapter Two

For my information on Charles Darwin, I used David Quammen's *The Reluctant Mr. Darwin*, and supplemented with Darwin's autobiography. The

introduction to the facsimile of Darwin's first edition of *Origin of Species* by Ernest Mayr was extremely helpful.

Loren Eiseley's *The Immense Journey*, was a highly influential text. For quotations in this chapter, I drew entirely from the first chapter, The Slit. However, many of his other works helped inform my thought including the essay, *The Star Thrower*, and sections from the book, *The Firmament of Time*, which also contain a discussion of Hutton and others who participated in shaping our understanding on time. Jonathan Weidenbaum's essay, "From Emerson to Eiseley: Two Religious Vision," and Ben Howard's "Loren Eiseley and the State of Grace" helped me to conceptualize Eiseley spiritual ideas. Though I did not include much biographical information about Loren Eiseley, his best autobiography is probably, Fox at the Wood's Edge by Gale. E. Christianson.

Chapter Three

This chapter is almost entirely based on an interview I conducted with Kirsten Nicolaysen in early 2013. She also gave me her published papers and the unpublished data from the cruise.

My sediment pile analogy to deep time relied upon introductory geology textbooks as well as Edwin Colbert's *Evolution of the Vertebrates*, found in amongst fossilized vertebrates in the Whitman fossil storage room. Loren Eiseley's *Immense Journey* contains a wonderful discussion of human evolution, and refers to the common ancestor as a prairie dog in "The Slit"

Chapter Four

Thanks to Alice, Liz, and Bob for company and the conversation that got be thinking about scale.

The USGS Tapestry of Time and Terrain is interactive available online: http://tapestry.usgs.gov/.

Chapter Five

All excerpts and quotes are from Gary Snyder's *Mountains and Streams without End*. I particularly focused my reading on "Endless Streams and Mountains," "The Mountain Spirit," and "Finding Space in the Heart," however, the each poem is best understood by a reading of the whole work. I also researched the poetry of Basho, who had a strong influence on Snyder. I have been fortunate enough to learn about Zen Buddhism from discussions on Buddhism from Akira Takemoto.

For the geology of Canyonlands National Park, I read *Canyonlands Country* by Donald Baars and the NPS free informational pamphlets.

Thank you to Clare Sobetski for your companionship and photographs, which are featured in Chapter 5.

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