Perspectives on the Age of the Earth and Why They Matter

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By

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Cambridge
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Publishing

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This book first published 2020

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-4385-4
ISBN (13): 978-1-5275-4385-0

Table of Contents

Preface

This book is about the gap in perception and attitude between the 44% of the US population that believes the earth is less than 10,000 years old, and those who accept the scientific determination that the earth is 4.56 billion years old. It is about investigating the age of the earth, and how that seemingly innocuous investigation links to what we think we know of science, to what we believe, and to how that knowledge and belief locate us in the context of a broader universe. It weaves together three points of view—personal anecdote, scientific and philosophical observation, and polemic. There are therefore distinct changes in tone–some sections are light reading, others are pretty dense, and yet others are, I hope, challenging to our comfortably accepted views of the world.

What I hope I have done in this book is to provide an entry, for a moderately literate audience, to worlds of science and philosophy that we normally do not ponder. In terms of science, this book discusses things that are more detailed than a typical high-school, or even introductory college chemistry class might discuss, but it stops well short of where research into fundamental chemical and physical principles has taken us. It is not difficult science, but it pokes its nose into an area of science that is not routinely treated in introductory textbooks. It discusses something of the philosophy of time, or perhaps more accurately, the history of the philosophy of time, to construct links between the issue of "the age of the earth" and the larger questions of philosophy, particularly the question of "how do we know?"

For me, the bottom line has been the daily wonder that what we define as the laws of chemistry and physics work, reproducibly and predictably. And they work not only in the laboratory that was my home for more than a decade, but in the laboratory next door, and in the laboratory in Paris, and in the one in Beijing. There is a fundamental reality that our separate experiments describe and verify. This leads me to believe–and I use that term intentionally–that what we have measured is correct, and accurate, within the uncertainties that attend our methods.

But we must be aware at all times that what we consider "natural laws" are our own descriptions–they do not, in any way, "govern" what occurs in nature. Nature is invariably more complex and subtle than our "laws" can possibly capture, and the result is that our descriptive "laws" will invariably only be approaches to truth or reality, to be updated and revised as our knowledge of the world around us becomes more detailed: this updating and revision is the necessary process of science.

There is a great joy and wonder for me in rubbing shoulders with new ideas. The wonder is because these ideas are the products of the greatest minds of my own species, and are accessible to me: the ideas are the cords that tie me to the history of humanity, and link me on the one hand to Plato, and Aristotle, and St. Augustine, and Kant, and on the other hand to Newton and Einstein and a host of other lights. The joy derives at least in part from my own ability to recognize that these ideas describe to some degree how I understand the universe–they resonate with my own experience. I can verify them. They also satisfy basic human urges–they satisfy my curiosity and my desire to explore. I am too timid to try physical exploration–climbing mountains and trekking across Arctic ice–but exploration of virtual space, the space of ideas, can be equally challenging. I hope this book allows you also to rub shoulders with ideas, to test them, to recognize that they are familiar and resonant with your own experience or are alien and out of tune, to use them to open new doors to understanding the world we share.

Science is a structure, much like a large building, with foundations, walls, and specialized spaces. There are scientists who are architects, who develop and design the blueprints of how this structure should be built. Newton was an architect; his work determined the pattern of this building's construction for roughly 300 years. It wasn't until Einstein, another architect, that major renovations were undertaken. But architects don't actually build buildings. Contractors and bricklayers do. I am a bricklayer. I try to provide good, solid bricks–things I call data–and try to place them carefully into the structure described in the blueprints. The perspective that I bring to this book is a ground-up, bricklayer's perspective.

I am deeply suspicious or distrustful of scientific models, a turn of mind that disqualifies me from being an architect. Models, sometimes parts of blueprints, are in themselves beautiful and can be made to be internally consistent. We can fall in love with them to the degree that we lose the forest because the individual tree is so enchanting. This is why measurable information is important to me. Models for interpreting measured information might change, but, if the measurement was done well, that information is a solid brick in the structure of the building we are constructing. Good models are required for science to function in one of its most important roles, in the role of predicting future outcomes and events, and thus providing guidance to those who establish the policies that govern our societies. Providing good data to these models is an honorable, if not glamorous, scientific function. This book looks at data and argues that they are good; it looks at models for interpreting those data, and argues that they are consistent. These two criteria–good data with consistent models–suggest but do not prove that the interpretations of those data are correct.

The building of science is a humbling and egalitarian process. Rare is the scientist who has never had to admit–"I was wrong." The people who are involved in building this structure come from all corners of the globe, and their only tickets for admission to the construction site are the willingness to work hard and the human capacity for reason. The literature citations–initials and a last name, usually–hide their genders and other human features, but the work we do does not discriminate by gender, or race, or nationality, or religion, or any other of a host of socially-conditioned discriminatory criteria: we are an equal-opportunity establishment. We do discriminate, however, between scientific and unscientific approaches to investigating reality: the latter, however defined, is excluded. In many ways, this process brings out the best in humanity.

Section I discusses how and why I ended up writing this book. Section II tries to illuminate how I think about the relation between science and religion, which is one of the fundamental issues in the discussion of whether the earth is very young or very old. The age of the earth is a subset of this larger topic, the relation between science and religion. It is also a subset, in part, of the question of whether evolution and creation are compatible concepts. Finally, looking at the broadest spectrum of issues, the age of the earth is a subset of the fundamental philosophical question–how do we know what we know, and how well do we know it?

Section III considers the avenues we have to knowledge, and traces the history of what humanity has thought about the age of the earth. In it, I emphasize what I regard to be the limitations of our knowledge, regardless of the sources from which we derive that knowledge. Section IV is a bite into complexity. In Section IV, I try to outline a simple, somewhat innocuous project that involved determining a geological age. It is intended to be a taste of geology in real life, a view into how geologists think, into the motivations behind our search for information, and our frame of reference for interpreting that information. I describe the layers of geologically relevant, but maybe chronologically irrelevant, features that were part of the landscape of this project. I ask you to consider what a realistic history or timeframe for these features might be, to answer the basic question–how long might this have taken? In other words, Section IV is an anecdotal view into how "knowledge" in a scientific sense is generated.

Section V is just science, and a little bit of the history of science. I try to show how the dating of rocks links to the other sciences we have, and to develop the notion that not all rocks can be dated, that not all dates are good, and that it takes a focused effort to match dating methods to specific materials so that reliable dates can be obtained. In arguing that an old age for earth is incontrovertibly supported by the best data, I respond to the arguments of those who assert that the earth is less than 10,000 years old, whom I call young earth creationists.

In Section VI, I address some philosophical and pragmatic notions that have developed in the young earth creationist literature. I find these notions inadequate as a basis for science, and thus dispute the idea that a truly "scientific" creationism can be built on them. Most of my scientific colleagues who have ventured into this discussion on the age of the earth have dealt only with what they know and are qualified to discuss, the scientific issues. In this section, I have chosen also to discuss issues that I have little qualification to address. Because the young earth creationist attack on the scientifically determined age of the earth proceeds not only with an assault on the nature and quality of the science that are involved, but also with an assault on the philosophy and social structure of scientific research, I try to understand, evaluate, and respond to the second prong of this attack, much as Section V responds to the first. Section VI also suggests that literalism in the interpretation of scripture is an inadequate approach to religion. Thus, I believe that a young earth creationist interpretation of the world around us is inadequate both as science and as religion. Section VII assesses where I think we stand in this discussion today, and where I think we can constructively make progress.

This book contains no new ideas. I have borrowed ideas mercilessly from other people and other books. I hope that I have given appropriate credit where it is due, otherwise you can accuse me of stealing ideas. The best I can say is that I have put these ideas together in some, I hope, readable form. I have read stuff (enough to confuse myself) and have tried to summarize it so that you don't have to. Some of that reading and thinking was a hard slog. But all along the way, this has been a fun exploration. I have given a list of reading materials at the back of the book, in case some of you want to follow branches of the path.

In some areas, my treatment of specific subjects is superficial. There are many things that I don't really understand, and this came home to me as I was writing this. I don't understand much about philosophy. I suspect that virtually every philosophical argument I make in this book has holes in it, and, in some cases, those holes may be fatal to my argument. I thought they made sense when I wrote them, and my ambivalence about philosophical arguments–some of them, I think, really are about how many angels can dance on the head of a pin, or about what the meaning of "is" really is–makes me want not to engage the pros and cons of these arguments in detail. It might well be that for some people, the philosophical arguments that a God cannot exist are convincing, and that the only level of existence that we can verify is this physical, mechanical process that we call life. I do not believe that, and choose not to believe that. Thus, my philosophical musings, though well intentioned, leave a lot to be desired. I ask your indulgence if I have made egregious philosophical blunders.

There are also many things about science that I do not understand. The cutting edge of physics today is well beyond me. I hope I have not misrepresented the conclusions and consequences of some physicists' theories. The nature of time cannot be discussed without at least a passing acknowledgment that modern physics has a lot to say about it. Fortunately, the slice of time with which I am concerned does not require detail or knowledge at the level that modern physics has reached. The best I can say is that I have tried to convey, accurately and faithfully, my experience and understanding of the corner of science–in many ways, the applied science–in which I have worked. I am not a theoretician, so I tend to view the world in brute-force ways–a measurement is either doable or not, and my curiosity drives me to make it as best I can. And I regard the age of the earth as a measurable thing.

There are likely places where I have ventured opinions or explanations in a knee-jerk sort of way, where I have either no business venturing an opinion, or where I haven't invested the effort to think through what I have said. I hope my unreflective reflexes don't mislead, misrepresent, or induce you to accept such reflexes without some forethought.

Thus, compared with volumes with titles like **The End of Time**, **Time Reborn**, and **From Eternity to Here: The Quest for the Ultimate Theory of Time**, or philosophical treatises with titles like **The Nature of Time**, **Objective Becoming**, and **Creation and the World of Science**, this book has a modest target. It deals with the small slice of time that delimits the existence of our planet and is measurable, with some accuracy, in the objects that exist on and around it.

The support of many people contributed to this book. I wish to thank, first and foremost, my parents, László Dudás and Sára Hansághy Dudás, for encouraging my curiosity and for forcing me to try to see things in as broad a light as possible. I thank my high school English teacher, Mr. Tom Crnich, for encouraging me to write and to continue writing. My undergraduate advisor at Montana State University, William J. McMannis, introduced me to doing geology in the field. My first exposure to isotope geochemistry was through Hiroshi Ohmoto and Peter Deines at Pennsylvania State

University. Deines was my role model of the true scientist: he showed me the discipline and meticulousness that work in isotopes really required. At the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, Richard Carlson and Steve Shirey introduced me to the intricacies of doing radiogenic isotope geochemistry. Also at Carnegie, the "Lunch Club" conversations with George Wetherill, Vera Rubin, Fouad Tera, Alan Boss, Paul Silver and others really stretched my concept of what it means to be a scientist, and showed me how to ask scientific questions. Less formally, colleagues at Carnegie, including Julie Morris and Sonia Esperanca challenged me to stretch my skills. I am indebted to Otto van Breemen at the Geological Survey of Canada, who took me on as a post-doctoral fellow. At the GSC, numerous colleagues, but particularly J.C. Roddick and Randy Parrish helped me think more systematically about how to do quality analyses. Also at the GSC, Anthony Davidson introduced me to the mysteries of the Grenville orogeny. Later, Sam Bowring, director of the radiogenic isotope laboratory at the Massachusetts Institute of Technology, saw fit to hire me to manage the tracer isotope section (Sr-Nd-common Pb) of his lab, and I am deeply indebted to him for this opportunity. At MIT, the list of supportive collaborators is long, including Jahan Ramezani, Pat Walsh, Mark Martin, Mark Schmitz, Blair Schoene, Becky Flowers, Julie Baldwin, Noah McLean, Terry Blackburn, Ann Bauer, and Chris Sherratt. My collaborations with Jahan and Ann continue today. Ann, formerly at Yale University, and now at the University of Wisconsin (Madison), afforded me access to library facilities at Yale, and discussed much of Section IV with me.

Personal supporters also deserve my thanks. These include members of the Bahá'í communities in which I lived over the years, but particularly my late wife, Rigel Lustwerk, who introduced me to the Faith in 1976, and critiqued early versions of Sections I, II, and III. Brian Aull critiqued early versions of Sections I – IV. The Bahá'í community of Debrecen, Hungary, deserves special thanks. They provided a haven for me while I wrote the bulk of Sections III, V, and VI. Especially, I thank Mahtab Naji and Mansoureh Karimi for companionship and encouragement. Mahtab assisted me in formatting the text prior to submission.

I thank Erica Evans at Yale, who did a lot of leg work in tracking down details of endnotes, and Susan Stengel, my wife, who has critiqued the whole text, except for Section V. Her patience, as I shirked my domestic duties while editing the final version, has been exemplary. Thanks are due also to Joel Stein, editor with Cambridge Scholars Publishing, who encouraged me to propose this book to his employer.

There are three illustrations in this book that were provided by Ann Bauer (Figure 4-10), and by Jesse Reimink (Figures 7-1 and 7-2). I give them thanks for permission to reproduce their work. I also thank the Institute for Creation Research for permission to quote extensively from their volumes **The Mythology of Modern Dating Methods**, and **Radioisotopes and the Age of the Earth**, volumes I and II. I thank Master Books, a division of New Leaf Publishing Group, for permission to reproduce Fig. 1 from **Rock Solid Answers**, and to quote paragraphs from the same volume. I thank the Literature Review Board of the National Spiritual Assembly of the Bahá'ís of the UK for a timely review of Bahá'í content, and the Bahá'í Publishing Trust of the US for permission to quote from Bahá'í publications.

Section I:

"We Didn't Mean to Go to Sea" (apologies to Arthur Ransome)[1]

Chapter One

Jennifer's Story

Ransome's story is about three children who are excited to spend a night aboard the sailboat of a family friend. The boat is firmly moored in the harbor, and the owner, an experienced skipper, is temporarily back on-shore, gathering food and supplies for the night's entertainment. A sudden storm blows up, and the sailboat ends up being swept out to sea, with children aboard, but no experienced sailor. This is fiction for adolescents, so of course the story ends triumphantly after the children survive a harrowing night at sea.

The story is a metaphor for my journey in writing this book. I wanted to write about a safe and innocent topic, the age of the earth, but I got caught in a storm that swept me out to sea in worlds that touch on the sociology of science and belief, on the philosophy of science and the philosophy of time, without a steady hand to help guide me home. So this book is what happened during that stormy night I spent out at sea.

Earlier in my career, I taught geology at a public university. I grew to respect my students, their work ethic, and their earnest desire to explore the world around us. I missed them when they graduated, or moved out of my sphere to take other courses. I was anxious for them to succeed. I was sometimes amused by their evaluations of me, sometimes perplexed, and sometimes rather irked. Of course they were entitled to their opinions of me, but I knew better, because I was the professor. There were instances when the students' evaluations relied on parental authority: "my parents think this assignment should be for a graduate course, not an introductory course." Parents knew better than I what level of instruction was appropriate for their children. So I learned that I was teaching not only students, but, sometimes, whole families. Some students brought their children to class when they couldn't find adequate child care.

Teaching introductory geology at a public university in the Bible Belt was interesting, because every semester there was at least one student who publicly or privately was willing to question geologists' "standard model" of the birth and evolution of our planet. Such questioning in most instances was really a key to mutual learning, because it indicated that a student had engaged the material. It provided excellent opportunities for demonstrating the process of science, for going back to the historical record of geology to discover how we've come to the interpretations we now have, and how different people view those interpretations. The students and sometimes I, also, had to be reminded that essentially all of our sciences grow out of the work of the "natural scientists" of the past millennium, many of whom were not only intensely religious, but were also ordained clergy. They did not abandon strictly biblical frames of reference without serious soul-searching and debate. The questioning student was walking in the paths tread by our ancestors, in the best traditions of science.

Such questions provided an opportunity to talk about the philosophy of science, and the distinctions between the observational evidence and deductive process of science and the "received knowledge" of Revelation, religion and faith. These, in fact, are the crucial issues in any classroom–the differences between fashioning new understanding and merely consuming "received knowledge." My goal was to help students make the transition from merely receiving knowledge to actively generating new understandings for themselves, to become independent thinkers, not only about science, but also about religion and faith. These are the issues that occasion intellectual, emotional and spiritual growth in both the teacher and the student.

In the classroom, these discussions led me naturally to acknowledge my own faith, and to let students see, some for the first time in their lives, a scientist who trusted both God and science. I could argue, then, that there was essential harmony between faith and science, while at the same time making it clear that the purpose of the course itself was to deal with the observations and interpretations of science, independently of our personal views of the world. I have no idea how much of this might have stuck with my students. Because of the obvious authority of the "perfesser" and the average undergraduate student's grade-consciousness, I had no independent measure of how or whether this particular message registered. The process of measurement perturbed the signal!

Jennifer was a graduate student who took my advanced course in isotope[1] geochemistry. She was one of six students, and was neither the best of them nor the worst of them. During the term, she did not stand out. She did the problem sets, handed them in late just as the majority of the class did, took the tests and complained that they were too hard, just as the rest of the class did. As required by the syllabus, she discussed the topic of her research/review paper with me within the first month of the term. Within two weeks of our consultation on her topic, as required by the syllabus, she gave me a list of 5 to 8 references that she intended to use in developing her review paper. Two weeks later, as required by the syllabus, she submitted an outline of the paper she was intending to write.

Then, two weeks before the end of the term, she asked me whether she could, or rather told me that she wanted to, change the topic of her paper. This is a slippery slope for a teacher. One the one hand, allowing such a change of course late in the term is not fair to the other students, and defeats the pedagogic rationale behind the assignment, the target of supervised research. The whole point of having graded assignments related to topic selection, to review of reference materials, to providing an outline of the paper prior to actually writing it, and to submitting a first draft, is to assure that points of contact exist between student and teacher. These points of contact are springboards from which I can learn from the information the student has uncovered and the attitudes the student brings to the project, in addition to exercising supervision, providing input and insight, suggesting course corrections, and assessing the progress of the student. With such a late change of topic, I would have to forego these checkpoints, the associated assignments, and the mutual learning process. On the other hand, forcing an unwilling or unhappy student to remain wedded to a research topic that is no longer of interest to her also violates a cardinal rule of good pedagogy–the need to capture the student's interest, and to cultivate it in a way that allows her to grow professionally, intellectually and personally. Given the choice between these two violations of pedagogic principle, I chose to let Jennifer follow her heart, without having the benefit of a topic review, a suggested list of references, a proposed outline or a first draft.

I don't remember (though I could probably look it up) what topic Jennifer had originally chosen for her paper. Her new choice was an analysis of pleochroic halos, and the implications of pleochroic halos for interpretation of radioactive decay. I found it peculiar that she chose this topic–we hadn't discussed pleochroic halos in class, and it was only during the first 8 weeks of our 14-week term that we worked on isotopic systems that involved radioactive decay. We were 4 weeks into study of stable isotopes when she asked to change topics–the change of topic wasn't obviously motivated by encountering new material as the term progressed. So what had happened?

I'll never know, because I never had a chance to speak with Jennifer later. She handed her term paper in along with her final exam, a set of take-home problems I had given my students a week earlier. Unlike the other students in the class, she never came by my office to pick up her corrected exam or her corrected and graded paper. To the best of my knowledge, she did not continue in graduate school beyond that term.

Pleochroism is a property of some materials[2]–naturally occurring minerals or synthetics–that we observe as a change of color when the plane of vibration of transmitted, polarized light is rotated with respect to a sample. This color change depends on the atomic, or more precisely, the ionic[3] structure of the mineral. The visible color of a mineral depends on

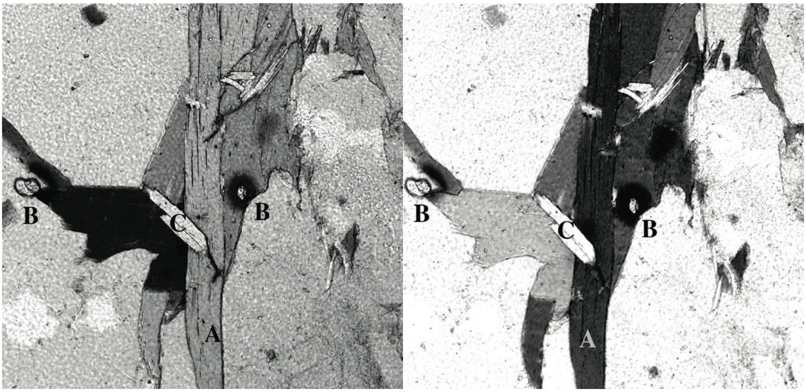

Figure 1-1: These are photomicrographs of a thin (30 micrometers) slice of rock through which light is transmitted. Cutting vertically through the middle of the left photograph, labeled A, is a grain of the iron-bearing mica, biotite. In this photograph, the waves of transmitted, polarized light are vibrating in the north-south plane, parallel with the mica sheets, and the mica is only lightly colored. In the same field of view, on the right, the rock slice is in the same orientation, but the plane of light polarization is rotated to the east-west direction: the same biotite mica grain is dark. This change of color is called *pleochroism*. The small diagonal grain slightly below the center of the photograph (C) is an iron-free mica called muscovite; it shows no color change due to rotation of the direction of polarization. To the left of the muscovite grain, there is another biotite grain that shows strong pleochroism, but because it is oriented differently than grain A, the pleochroism in this case is dark in the left image but light in the right image. Very small grains near B in these photographs are U-bearing zircon grains that have dark halos. Regardless of pleochroism and orientation, these halos remain dark because the biotite structure has been damaged by radiation from the U in the small zircons that are at the center of the halos. Near the left margin of the photographs, a zircon is only partly surrounded by biotite, and radiation damage is not visible in the other, iron-free minerals around it. All photos are from a sample of granite from Billerica, Massachusetts. The field of view is about 1 mm (1000 micrometers) wide for both photographs.

the wavelengths of light from which the chemical bonds in it absorb energy. If the bonds in the mineral are strongly oriented, as they are in the sheets of a mica mineral, for example, then changing the orientation of the polarization of light can change the degree to which the mineral absorbs the light, hence changing the visible color of the mineral. Pleochroic halos (Figure 1–1) are discolored zones that form in some pleochroic minerals due to the damage caused by alpha particles emitted during decay of radioactive atoms. In pleochroic halos, the color change–pleochroism–is obliterated, indicating that the ionic structure has been damaged or completely destroyed by the alpha particles released during radioactive decay. Alpha particles, which are highly energetic helium nucleii, make Swiss cheese out of the mineral's structure, much like bullets perforate a tin can or a highway sign. Where exceptionally high concentrations of strongly radioactive atoms–generally uranium or thorium–are locked in almost any solid for a long period of time, some structural damage from alpha radiation is likely,[4] and the modification of color in pleochroic halos is a telltale sign of this process.

Most pleochroic halos, such as those illustrated in Figure 1-1, are less than 100 micrometers (a tenth of a millimeter) in diameter. They are a microscopic and rather obscure feature in the firmament of phenomena studied by geologists. If we attempt a classification of "scientists" so that we can locate who in the world might know about pleochroic halos, we might consider "geologist" to be a "genus" in the larger "family" of scientists. Within this "genus," we can identify "species," such as "paleontologist"–a geologist who studies fossils, or "sedimentologist"–a geologist who studies processes that generate sediments, and ultimately, sedimentary rocks, or "mineralogist"–a geologist who specializes in studying minerals. Within the species "mineralogist," there might be a "subspecies" of scientists who specialize in microscopic techniques of mineral identification and description: it is in this subspecies of geologist that we find scientists who would immediately recognize both the term "pleochroic halo" and the object itself when they see it under the microscope. It is probable that a majority of geologists who are not petrologists (the "species" of geologist who studies rocks in detail) or mineralogists is unaware of the existence of pleochroic halos. Jennifer's paper, based on three citations from the scientific literature, concluded that because we can't explain the existence of specific types of large, multi-ringed pleochroic halos with the data we have on the energetics of alpha decay, we must question the accuracy and reliability of our theory of radioactive decay, and hence, the reliability of the half-lives of the radioactive isotopes we use for dating geologic materials. So pleochroic halos have a certain David vs. Goliath appeal–they are microscopic features that, if Jennifer's analysis were true, have the potential of bringing down the whole house of age dating based on radioactive decay.

I was stunned and incredulous as I read her paper. My mild initial reaction was to wonder whether she had misunderstood the process and fabric of science so completely that she was willing to question the very large body of work done on radioactivity by chemists and physicists, not to mention geologists, over more than 80 years, simply because one set of observations was not yet completely understood. It is rare in any field of science to have no unexplained phenomena, no loose ends–unexplained radioactive halos didn't trouble me as much as they obviously troubled her. From my perspective, her conclusion amounted to throwing the baby out with the bathwater.

The paper was, in concept and execution, beyond the range of capabilities that I expected from Jennifer, based on her performance during the rest of the term. In class, we had not discussed the energetics of any radioactive decay mechanism in detail; we had simply acknowledged that all decay reactions liberate energy, primarily in the form of heat, and matter in the form of neutrinos or alpha particles, and daughter nuclides.[5] It was obvious from the paper that Jennifer–kudos to her!–had in fact learned quite a bit about the energetics of decay. I trusted that she had written the paper herself; I doubted that it was a "paper-by-contract" written by someone else. She made the relatively sophisticated argument, following, for the most part, arguments in a paper she cited by Robert Gentry,[6] that multi-ringed pleochroic halos–unlike the unzoned halos in Figure 1-1–necessarily represent damage zones formed by alpha particles of specific but different energies–inner rings were due to alpha particles of lower energy, whereas outer rings were caused by alpha particles of higher energy. The inner, darker zones had more intense structural damage, whereas the outer zones were less impacted by radiation. The multi-ringed halos essentially demonstrated the stopping power of individual minerals with respect to projectiles–alpha particles–of different energies. The paper then linked these different energies to specific steps in the decay chain of uranium nucleii,[7] and argued that no alpha decay in the decay chains of uranium or thorium was sufficiently energetic to form the largest observed halos. Additionally, one of the halo types required the presence of a polonium isotope whose half-life was a mere 164 microseconds–and which therefore could never have been present in sufficient concentrations to generate macroscopically observable halos. These two proposals–that no known alpha particle was energetic enough to cause the largest halos, and that halos suggestive of a very short-lived nuclide were present–led Jennifer to the conclusion that these halos were physical evidence of special acts of Divine creation, physical evidence that required processes that were not now observable, and could only be understood in the framework of a young-earth creation model. Jennifer's term paper, in other words, was simply her way of saying, at the end of the term, that she didn't consider isotope geology as valid science.

The light went on. I was not dealing with a term paper for a graduate course in isotope geochemistry–I was reading a "creation science" treatise. Jennifer was not interested in learning how geochemical or isotopic data–physical observations–provided the basis for assessing the validity of theories or concepts that attempt to describe the world around us. She was a student for whom the conceptual framework of religious belief provided the criterion of "truth," and for whom geochemistry or isotopes were useful only when they could be used to support a pronouncedly non-scientific description of the physical world. So Jennifer elicited my resentment and anger–I had wasted my time on someone who had closed her mind, did not have the intention either of listening and learning, or of sharing openly so that others could learn from her. Jennifer also elicited sadness: an intelligent and motivated person had been trapped by a fundamentally irrational and materialistic view of the world, had been sold a bill of goods that ultimately, from my perspective, would limit her to accomplish less than her God-given talents would have allowed, had she given herself the freedom of an open mind.

This was my first head-to-head encounter with "creation science." This was when the seed of the idea for writing this book was first planted. Subsequently, I reviewed the references Jennifer had used, and found others–mostly within the creationist literature–where the arguments contained in Jennifer's paper had been developed. The pleochroic halo argument continues to be used in some creationist circles as physical evidence for special Divine intervention in ongoing, present-day processes, and as evidence of essentially instantaneous Divine creation. It is discussed in greater detail in Section VI. The crux of the argument is the argument from ignorance: if we don't understand it, it had to be God. This is the argument that our ancestors used for earthquakes, volcanic eruptions, and smallpox–because we didn't, at some point in the past, know what caused them, we interpreted them as acts of God. It is also the argument of much of the "intelligent design" movement. The progress of science, from this point of view, leaves fewer and fewer acts of God, fewer and smaller "gaps:" it is a precarious base for faith.

The immediate issues I had to address were how to grade such an assignment, and how to grade such a student. In the pedagogical literature, there is an ocean of material addressing issues of assessment, and, though I am not familiar with this literature, I am certain that I would find educators who would intensely disagree with my subsequent choices. I think grades should not be based on intent, or potential, or my expectations of what a student might or might not think, believe or know. Grades should be based on the student's performance alone. This is essentially an existentialist position: the student's grade is defined by the corpus of work completed within the framework of the syllabus of the course, not by the extent to which that corpus of work matches what I expect the student's ability to be. If I am teaching a genius, like an Einstein, I don't grade the genius on his "genius-ness," his capacity or my expectation of his capacity, I grade him on his specific performance in the course. If he doesn't turn in the term paper, he gets an F for that assignment, and that F gets calculated into his final course grade. To the extent that Jennifer had completed the assignments, taken the tests, and behaved like a student who shared the fundamental assumptions of "science" in all contexts but the last assignment, I had no qualms in assessing her performance by the same criteria I used for the other students. But what about the term paper? Did it meet the requirements of the assignment? Was it science? Is the *attitude* toward science that the term paper revealed a criterion for my assessment of the student's performance as a scientist-in-the-making? At what point should I, as teacher and scientist, make the determination that this student–or any student, for that matter–is not fit to continue working as a "scientist?"

One of my classmates in graduate school had tremendous difficulty working cleanly in the chemistry laboratory. Once, he dropped an Erlenmeyer flask containing some reagents. He stared at the shattered flask, the solution spreading on the floor, and commented: "I guess the flask wore out." He was intelligent, funny, and hanging out with him was truly enjoyable. Hanging out with him in the lab was dangerous. Was he cut out to be a lab scientist? No. Should he pass a laboratory science course? Probably not. Is Jennifer's situation much different? In her case, it wasn't a physical incapacity to hold on to a flask, but a willful decision to abandon basic scientific methods for decision-making and data assessment.

If I were to make the determination that Jennifer was not fit to be a scientist, how should I act on it? If I were, in private consultation with her, to suggest that she not continue studying science, or perhaps more aggressively, to suggest publicly to the department's faculty that they discontinue providing her a graduate student stipend, would I merely be another part of the "establishment" of science that denies opportunities to "creationist scientists"?

The other, less immediate issues I needed to address related to self-preservation. How can I protect myself from being blind-sided in the future? To what extent and how aggressively should a non-tenured, junior faculty member expose himself on such a potentially divisive and controversial issue? Finally, dealing with Jennifer's term paper illuminated fundamental philosophical issues: what are the relationships between my personal religious beliefs, my activities as scientist and teacher, and the attitudes, values and functions of the society around me?

In a simple way, the issues are these.

If a graduate student in a scientific discipline did not have the preparation and sophistication to understand that the arguments about radioactive halos are not substantial or logical–why should the broad generality of the population fare any better in assessing potentially conflicting claims about a host of scientific issues? The parent who thinks a problem set for an introductory course is appropriate to a graduate course has made an assessment of the level of science his child should know: is that level of knowledge enough?

If a graduate student in a scientific discipline could intentionally misrepresent both her interest and her values in the service of her chosen religious beliefs, why should we not expect other professionals–scientists, doctors, lawyers, journalists, politicians, clergymen–to behave similarly, to manipulate our social institutions for personal goals? Though these goals are sometimes rooted in broadly positive values ("I am doing the will of God;" "These are basic family values," etc.), the manipulation of social institutions will not always be restricted to such positive values, and how do we, as a society, protect our institutions from such subversions? Is manipulation for "positive values" really benign or beneficial, if it destroys our trust in our institutions? We know that ends do not justify means–when as a society do we call a halt to justification by ends? And if our social institutions–particularly our sources of information–are manipulated for personal goals, what reliable sources can we access to make informed and rational decisions about broad social issues? In other words, is there any way to avoid suspicion and polarization in our public discourse on issues of global survival? Is rationality enough for our decision-making, or do we need shared ethical constructs as well, so that we can trust that information and intent are factually reported?

Very rapidly, the simple problem of assessing an assignment for a science course evolved into a rather daunting philosophical issue: what is science, what is religion, how do those two relate, and how do we make decisions when we get apparently conflicting messages from them? Independently of how philosophers, or practitioners of science or religion view them, it is important also to understand how the public at large views these questions. What values does "the average person" use in making decisions on issues that may involve somewhat different interpretations from the scientific and religious communities?

A potential response that is open to "the average person" when confronted with such decisions is a retreat into the familiar–a retreat to dogmatism, or a conservative exclusion of the unwanted, new information. The fear of embracing and incorporating the new into our view of the world is that perdition lies along that path: "*Abandon hope all ye who enter here.*"[8] Another possible response is the other extreme—agnosticism or nihilism, what Yeats described as *"the best lack all conviction."*[9] The challenging response of the scientist ideally is that of Archimedes–*"Give me the place to stand, and I shall move the earth."*[10] The difficulty with that position is that we may have no place to stand–we may not be able to depend on any of our sources of information. The US government disguised advertising or propaganda as news: in the aftermath of the war in Iraq, it paid soldiers to write positive "news" stories for publication by the Iraqi press.[11] Because there is a political investment in denying that climate change is real, the US government has prohibited its agencies from using the words "climate change" in any public document, or on any official website.[12] And political figures, when queried about issues that involve science and faith, but also have ramifications for public policy, are unwilling to commit to a specific position, and abdicate the "leadership" role to which they aspire.[13]

From my perspective as a scientist, I felt that Jennifer's paper reported misinformation about pleochroic halos. I wanted to trace the source of the misinformation. Perhaps equally importantly, I wanted to understand whether such misinformation was really the product of misunderstanding by someone who was fundamentally well-meaning, or if it was an intentional misrepresentation–a purposeful manipulation. In the pre-Google era, tracking sources of such information could be a non-trivial task, particularly if the information was not in the mainstream media–in scientific journals or books from recognized publishing houses. In the post-Google era, the task of tracking has become easier, but the absence of editorial oversight or peer-review of web-based content means that misinformation can take on a life of its own, and misinformation in one source becomes a fact in a second, and provides the tools for manipulation in a third.

The issue is not simply an issue of philosophy. It is an issue of people, and people's intentions. In Jennifer's case, her science could not be separated from her intent, nor can her religion be separated from her intent. The teacher in the science course, without wanting to, and sometimes without realizing it, gets caught in making personal assessments of the intent of the students. And all the science training in the world cannot prepare the teacher for that. So, I have come full-circle: it may not be possible to assess a student's performance without assessing intent, and therefore, without assessing abilities and expectations. More broadly, in our public discourse, we have to deal both with factual information and with moral values, and we need a perspective that is broad enough to accommodate both.

Chapter Two

Fast Forward

Fast forward several years, to my second encounter with "creation science," and the immediate impetus behind the writing of this book. A colleague of mine brought a book to the lab where we worked. Titled **The Mythology of Modern Dating Methods**,[1] and unlike *Sex in the City*, it does not deal with current urban myths about personal relations between people of opposite gender. Written by John Woodmorappe and published by the Institute for Creation Research (ICR), it is a compendium of the perceived failures of isotopic geochronology.

My first, overwhelming reaction to **Mythology** was sadness–not because of the alleged failures of isotope geochronology, nor because of the alleged stubborn closed-mindedness of the "scientific establishment," but because a self-professed Christian and a Christian publishing institution had seen fit to release a piece of work whose attitude and tone struck me as rather un-Christian. My perception of faith, of religion, and of Christianity in particular, is that, beyond its primary goal of affirming faith in God, it is meant to uplift the spirit and to train the individual–heart, mind and soul–to be gentle, loving and patient with those who choose not to view "truth" from our own chosen perspective. **Mythology**, in my estimation, is not gentle, loving or patient. It does not, in any way, "turn the other cheek." Woodmorappe is explicit in addressing and rationalizing this:

> "**Myth:** Criticism of isotopic dating by Woodmorappe involves intemperate language.
> **Reality Check:** …Recall the words of the immortal Martin Luther: 'I cannot deny that I am more vehement than I should be… But they assail me and God's Word so atrociously and criminally that… these monsters are pushing me beyond the bonds of moderation (Gritsch 1993, p. 35)."[2]

Once again, I wondered whether the end–service to the creationist Christian community–justified the means. I was fairly certain that John Woodmorappe was not a modern-day Martin Luther,[3] and, from my perspective, Woodmorappe was not defending God's Word. For the most part, God's Word defends itself quite well enough.

Because I worked in a laboratory whose daily bread is isotope geochemistry, and primarily radiogenic isotope geochemistry applied to dating of rocks, my immediate circle of colleagues ridiculed the book. To the best of my knowledge, my colleagues are not religious people, but the ridicule came not because the author was a Christian, but because the book was not science as we know it. The format of the book is certainly unconventional—each statement about dating methods that the author characterizes as a "myth" is followed by a "reality check" or "fact"—and does not lend itself to the kind of reasoned argument to which we are accustomed in most scientific works. It has some of the trappings of science–an extensive bibliography, for example–but it unequivocally separates itself from the dialog and prerequisites of science:

> "**Myth:** Scientific creationists are obligated to explain isotopic dating methods before anyone can begin to seriously doubt the validity of these methods. **Reality Check**: Creationists are under no such obligation, for the simple reason that the burden of proof is on the uniformitarian and not the creationist. This stems from the fact that it is not creationists who are trying to have it taught as fact that the earth is young: it is uniformitarians who are dogmatically claiming that the great antiquity of the earth is virtually proven fact, and doing it with no small amount of intellectual arrogance."[4]

My perception of science is that it represents a dialog between alternative interpretations of information, where choices can be made between alternatives based on their interpretive power, and on the tests they suggest for further exploration. If creationists bring no alternative interpretation to the discussion, how can our consultation about *science* go forward? Merely denying the utility of a theory–in this case, the theory of dating based on radioactive decay–without suggesting alternative interpretations for the observations that provide the foundation of the theory, is not science. If "creation science" wishes a place at the conference table of the sciences, it needs to play by the rules of that table, and the ante for getting into the game is that observations need to be explained by testable (i.e., scientific), alternative theories. If the agenda of the creationists is to change the rules of the table, to change the rules by which we do science, then we have a significant philosophical issue to address, an issue that extends well beyond the scope of **Mythology** and this book, though I approach discussion of this in Section VI. I sense something here that feels much like Jennifer's term paper–somewhere there is a baby that is being thrown out with the bathwater.

Woodmorappe adds commentary on the arrogance of scientists:

> "Some individuals just cannot face reality and come to terms with the fact that many intelligent believers have dared to question the sacred cows of rationalism (not the least of which is the great antiquity of the earth). Since this is just too much for some rationalists to bear, they must resort to the denigration of the intellectual capabilities of those who disagree with them."[5]

Some Christians also come in for hard words:

> "…whatever it is that the apologists for isotopic dating have to say, compromising evangelicals will swallow it hook, line and sinker. Then again, this is far from the only way that compromising evangelicals have shown themselves to be no less steeped in rationalism than the card-carrying atheistic humanists."[6]

Thus, in a book that is nominally about the science of dating, there is sociological interpretation and psychological observation, neither of which falls within the purview of the science of radioactive dating. In these passages, rationalism is equated with godlessness, and one of God's greatest gifts to humanity, our ability to reason and to do science at all, is considered a fatal flaw. We might draw the conclusion that in order to be a "creation scientist" one must not be a rationalist. Inasmuch as the basis of science as we know it is the use of our rational faculty to observe, test and interpret the world around us, Woodmorappe's explicit suspicion of rationalism removes his work from the realm of science. I hope to return, later, to the relationships between rationality, faith and science.[7]

Needless to say, **Mythology** left a very sour taste in my mouth. There are three bites that tasted particularly sour, and, interestingly, these were matters more of context than of explicit statement: these are my reactions and interpretations from what I read.

The first bite that was difficult to swallow was the implied accusation that isotope geochemists who are involved in dating geological events are driven by the goal of discrediting the Biblical narrative of creation, that essentially, every morning when I wake up, my first thought is "How am I going to stick it to the creationists today?" Nothing could be further from the truth for me personally, or for the vast majority of my colleagues. We do science because we want to answer scientific questions, not because we are concerned about the veracity of scripture. Sadly, I suspect most of my