ABSTRACT

Thomas Kuhn and Abiotic Oil

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The dominant theories of oil generation are fossil fuel and abiotic oil (the latter also known as the abiogenic or R-U theory). For decades, United States scientists have held that oil is created by decaying life forms from millions of years ago. Abiotic theory (that oil is created without biotic particles) has historically been dismissed in the United States; however, it has gained new prominence among some scientists as the result of an experiment in 2002 that theoretically proved its validity. Despite this and other evidence seeming to disprove the fossil fuel theory, fossil fuel theory not only clings to life, but thrives. Why? Because science is not the ever changing, eager to self-correct, and unbiased force that its supporters like to claim. Thomas Kuhn, in his book *Structure of Scientific Revolutions,* explained that contrary to popular belief, science is a social construct fits facts to theories, rather than fitting a theory to the facts. The majority of scientists accept the theory, then vigorously resists change even when it is clear beyond a reasonable doubt that current thought is flawed (recall Copernicus).In this paper, we will examine both fossil fuel and abiotic theories, the evidence of any anomalies, and how this new discovery could potentially have very strong consequences.

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THOMAS KUHN AND ABIOTIC OIL

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CHAPTER ONE

Introduction

For years now, the United States government and many other organizations have been saying that oil is running out and that we desperately need to find alternative sources of fuel. Companies specializing in petroleum said that they are always finding new methods that allow us to drill in places we could not drill before, making these concerns unimportant.[1] However, the issue the companies always seemed to avoid was the question that oil was running out. In 1965, Marion King Hubbert claimed that oil production would soon peak and that the rate would soon start to decline[2]. Hubbert's claims, at least for the present, have proven unfounded to some degree.[3,4]However, logic would dictate that if oil is a finite resource, as the fossil fuel theory claims it is, then eventually, at some point in the future, we're going to run out of oil. This worry about an inevitable lack of oil is motivating much of the push towards finding alternative energy sources like wind, solar, and water. Problems with these current efforts, however, have raised questions about the efficacy of these new methods.[5,6,7] As it stands now, there is no

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[1]http://www.chevron.com/deliveringenergy/oil/drillingcompletions/

[2] http://www.hubbertpeak.com/hubbert/1956/1956.pdf

[3] OPEC's website states, "At the rate of production in 2011, OPEC's oil reserves are sufficient to last for more than 109 years, while non-OPEC oil producers' reserves might last less than 19 years.") http://www.opec.org/opec_web/en/press_room/179.htm

[4] In reference to Canadian Oil Sands, "New projects are being added every year and production is expected to increase from 1.31 million barrels per day in 2008 to 3 million barrels per day in 2018, keeping pace with demand and providing a sound economic basis for the future." http://www.energy.alberta.ca/ourbusiness/oilsands.asp

[5] Problems with Wind: "In 1998, Norway commissioned a study of wind power in Denmark and concluded that it has 'serious environmental effects, insufficient production, and high production costs.'"

clear picture about what's going to happen when oil really does start to run out, thus the need to find an alternative to drilling for fossil fuels seems like a valid concern. This may not be the case. In the United States, the theory of Biotic Oil (the theory that hydrocarbons that come together to form oil are generated from dead animals, usually dinosaurs and dead plants) is absolutely dominant. To question the theory, to say that fossil fuel theory is false is to be labeled either a heretic or a fool, depending on which scientist you ask. In Russia, however, a different theory is dominant – the abiotic theory of oil. The theory states that the hydrocarbons that come together to make oil are actually produced by the earth itself, in the magma, rather than from decomposing organic compounds. For years, the abiotic theory of oil had been dismissed by prominent scientists in the West as being at best fantasy and at worst, lunacy. Recent evidence, however, in the form of a study published in 2002 in the Proceedings of the National Academy of Science (NAS being THE science authority, for those who are unfamiliar

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See the full research and findings behind the study for further detail at: http://www.aweo.org/problemwithwind.html#I

[6] Problems with Solar: "In order to meet the energy needs of the US entirely with solar power, we would need to cover 0.2% of the land area of the United States with photovoltaic cells, roughly equal to the area of paved roads in the US. And that's using solar cells with an efficiency of 50%, not too far below the theoretical maximum for a single-layer device… He pointed out that in order to build that sort of solar energy infrastructure, we would need to produce and install 2,000 square kilometers of solar cells a year for twenty years. To put that in perspective, we currently produce about 200 km^2 of plastic film a year– plastic wrap, garbage bags, etc.– so we're talking about producing complicated solar cells at ten times the rate that we make plastic wrap. That's what they call a "significant technical challenge."" (original cite: http://scienceblogs.com/principles/2007/10/18/the-problem-with-solar-energy/) (credited author within original citation: Peter D. Persans— Professor of Physics, Applied Physics, and Astronomy, Rensselaer Polytechnic Institute).

[7] Problems with water: "The disadvantages of hydroelectric energy include: the high potential for extreme damage to the local ecosystem; the high cost of construction; the sheer size and scale of hydroelectric dams and the possibility of the potential devastation of a dam breaking. All of the problems associated with large scale hydro are themselves potentially very large due to the scale of the construction. The environmental impact of a poorly built dam cannot be understated; hydroelectric energy also has one of the highest rates of death per kW (due to a few accidents where dams breaking have taken many lives.)" http://howtopowertheworld.com/disadvantages-of-hydroelectric-energy.shtml

with it) proves that the abiotic theory can no longer be easily dismissed as nonsense. Not only is abiotic oil theory a viable theory, but the study proves that abiotic theory explains key points of how oil comes to exist that cannot be explained by traditional fossil fuel theory.

We are on the verge of a major paradigm shift, or at the very least, on the verge of a major paradigm debate between the two camps of fossil fuel theory and abiotic theory. This debate will have major ramifications, for if it is accepted that oil is a renewable resource, generated by the earth itself, there could possibly be no alternative energies needed to replace oil at all, or at the very least, current alternate energy research could potentially be shifted to supplement oil drilling, rather than replacing it. Thomas Samuel Kuhn, author of the notable scientific work, *The Structure of Scientific Revolutions*, put forth his idea of the scientific paradigm. At the time of its publication, mainstream scientific theory had three main proponents of three different theories of science. There were the logical positivists, there was Karl Popper, and there was Willard Quine who held theories that advocated for *verification*, *falsification*, and a *web of beliefs*, respectively. The logical positivists argued that we, as humans, can know everything there is to know about the world through science. They argued that science is used to prove theories true, and thus generating knowledge. For example, a logical positivist would argue that if John took a piece of cloth, lit a match, and lit the cloth on fire with the flame of the match, then we now know that cloth burns, thus we have learned an objective truth about cloth that no one can deny – it burns.

Karl Popper disagreed strongly with the logical positivists. He argued that verification is impossible, that science can never actually prove anything beyond a shadow of a doubt, as the logical positivists claimed, because all scientific claims come down to inductive logic. For example, the sun has risen in the east and set in the west every day that humans can remember. However, that does not guarantee that tomorrow the sun will rise in the east and set in the west. It is very likely, given its past, but it is not guaranteed. Take our example about the burning cloth. We can know only that the cloth burned *this time*. We cannot know that every cloth we attempt to burn will burn. We cannot even know that if we attempt to burn a cloth tomorrow that is similar in every way to the cloth we burned today that it will burn, or burn in the same way. Instead, Popper used the analogy of pounding stakes into a swamp to represent how science works. Every time an experiment is successful, the theory it was testing is reinforced – much like pounding the stake deeper into the swamp. Even though the stake will never reach stable ground in a swamp, pounding it deeper and deeper into the swamp makes it *more* stable. Popper thus argued that while scientific theories could be reinforced, they could never be proven. Going further, Popper argued that scientists should make grand hypotheses with multiple locations for falsification and then proceed to attempt to falsify them. While this was likely a very depressing theory for many scientists (after all, most people want to work to support and prove their ideas true, rather than work to tear them down), it was the currently accepted theory of science when Kuhn came onto the scene.

Also at work on a theory at the time was Willard Quine. Quine, while not having the dominant theory at the time (as Popper did),was still influential in the scientific community. Quine argued for a web of beliefs – he argued that rather than there being any objective truth that science could prove, facts were always interpreted. At the core of this web were beliefs that were strongest for each person – such beliefs might be those like belief in God or that one is a man or a woman. Beliefs on the outer edge of the web would be more prone to change – such beliefs might be like you heard it was going to rain today, if it didn't rain, you would quickly change your beliefs about whether or not it would rain today. Quine argued that the logical positivists were wrong in saying we could know objective truths, because we are subjective people with limited knowledge and various beliefs that color our interpretation. For example, we all saw the cloth burn, but *why* did it burn? If you ask three people why it burned, one might give the chemical composition of the cloth, say that there are a few things within it that burn, that they are the most prevalent things in it, thus it burns. A second person might argue that the reason it burns is because it's dry, but that if wet, none of those chemical compositions the first person mentioned would matter. A third person argues that cloth burns simply because the match was close enough, if the experimenter held the match further it would not have burned. Which of the three people are correct? All of them? None of them? Some of them? This was the crux of Quine's argument – we all see the cloth burn this time, but we all come up with different explanations about *why* it's burning. Quine's theory would prove similar to Kuhn's in that both argued that science not very objective at all (as the logical positivists and Popper claimed), but was rather very subjective. It might also be argued that Quine's theory was a strong influence on Kuhn's own thinking.

CHAPTER TWO

Relative Science and Thomas Kuhn

Throughout most of history, science has prided itself on finding out the truth of things. Many scientists (and many non-scientists) look at science as a surefire way to figure out what something really is. For many people who disapprove of religion and faith, science is the very religion they faithfully cling to, while claiming it is special and unique – that it is not based on faith or trust, but facts. The so-called "new atheists" will serve well to show the modern view of science that many people hold to some degree or another. While religion will be mentioned briefly by the four men that will be referenced, the prominent point for this paper is their collective opinion on science, not religion. The four men who will be looked at are Sam Harris, Daniel Dennett, Richard Dawkins, and Christopher Hitchens. All four are well known for their dismissal of religion and their steadfast faith in science. We will look at comments all four men have made, and the implications these specific comments invoke. None of the selected comments are meant to define the particular beliefs of the men quoted. Rather, the implications from their comments will serve as examples of a popular view of science that is currently held by many people. Next, we will cover specifically what Kuhn himself believed in his book *The Structure of the Scientific Revolutions*, and finally, we will apply a Kuhnian critique to all four of the comments selected.

Sam Harris argued that science constantly moves forward and progresses year to year. He writes, "If religion addresses a genuine sphere of understanding and human necessity, then it should be susceptible to *progress*… Whatever is true now should be *discoverable* now,and *describable in terms that are not an outright affront to what we know about the world*"[1] (emphasis in original; emphasis added). Harris thus implies we do in fact know particular things about the world for certain – through science.

Christopher Hitchens argued that faith cannot stand up to human reason, and that we now know so much more about the universe than we used to know. Hitchens writes:

> Faith of that sort – the sort that can stand up at least for a while in a confrontation with reason – is now plainly impossible. … Religion comes from the period of human prehistory when nobody… had the smallest idea what was going on. It comes from the bawling and fearful infancy of our species, and is a babyish attempt to meet our inescapable demand for knowledge. … *Today the least educated of my children knows much more about the natural order than any of the founders of religion.…*[2] [emphasis added].

Hitchens thus assumes there is knowledge that is certain about the way of the world. He thinks that even his children can be sure about how the world functions, now that it seems science has proven so much to be true.

Richard Dawkins provides his own analysis: "It is in the nature of faith that one is capable…of holding a belief without adequate reason to do so.… Atheists do not have faith.…"[3] Dawkins then, who believes in science's ability to provide for the truth, and considers himself an atheist, would thus argue that science does not require any sort of faith, but that it is simply accepting obvious truths.

Daniel Dennett, the last of the four men we mention, will conclude with his views on science and religion, writes of religious people, "They may be right, but *they don't know*. The fervor of belief is no substitute for good hard evidence, and the evidence in

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[1]Harris, Sam. *The End of Faith.*

[2]Hitchens, Christopher. *God Is Not Great*. [S.l.]: Chivers, 2008. Print.

[3]Dawkins, Richard. *The God Delusion*. Boston: Houghton Mifflin, 2006. Print.

favor of this beautiful hope is hardly overwhelming."[4] Dennett then, implies that good hard evidence can be had for other beliefs, which he would apply to science.

The comments made by all four authors will find themselves critiqued by Thomas Kuhn – himself a non-religious scientist. We will return to them soon.

What then, did Thomas Kuhn's work and beliefs from *The Structure of Scientific Revolutions* argue about science? What did Kuhn really think of science? We will see.

Unlike Karl Popper before Kuhn or the logical positivists before Popper, Kuhn did not believe science was in any way designed or capable of finding any truths. Science, to Kuhn, certainly did not verify anything, as the logical positivists claimed, but nor did it ever falsify anything, as Popper claimed. Rather, science settled on a conception that people agreed on, and didn't change *until overwhelming evidence was presented* against the old theory *and a new theory was presented*. This accepted theory that guided all scientific research within its field was the "paradigm." For example, the paradigm of celestial science before Galileo and Copernicus was that the sun orbited around the earth in a geocentric universe. Everyone doing celestial research assumed that the sun orbited the earth and made their deductions from that starting point. After Copernicus, the belief that the earth orbited the sun, the heliocentric universe, replaced the old paradigm and became the new paradigm. From then until today, all celestial scientific research assumes that the earth orbits the sun and begins from that point.

Kuhn believed there were three stages of science that occurred in a cycle. First was pre-paradigm science which led to normal science once the scientific community adopted a paradigm.

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[4] Dennett, Daniel Clement. *Breaking the Spell*. London: Allen Lane, 2006. Print.

Second, normal science (what most scientists did on a day-to-day basis – going to the lab and conducting experiments)was conducted. While normal science was conducted, inevitably anomalies would occur within the theory (such as why planets appeared to have very strange orbits in the geocentric universe, for example). As normal science was done, more and more anomalies with the paradigm would be discovered. Eventually these anomalies would cause a "crisis" within the scientific community, which would lead to extraordinary science. This extraordinary science was scientific research done in an attempt to replace the current paradigm with a new one that explained all of the anomalies generated in the first paradigm.

The third part of the cycle was where extraordinary science caused a paradigm shift – the bringing in of a new paradigm to replace the old paradigm. This would only occur once a new paradigm was acceptable to replace the old, anomaly-ridden paradigm. Once the paradigm had shifted, normal science would resume and the cycle would start anew – the only difference being that there would never be pre-paradigmatic science once the first paradigm was established.

Kuhn argued that this cycle did not ever really progress toward some truth, but rather just set up a new paradigm that was agreed upon by the scientific community. The new paradigm need not be any more *right* than the old paradigm; it merely needed to explain the old anomalies. The new paradigm would inevitably generate its own anomalies through normal science that used it, which would eventually lead to another crisis, and yet another paradigm shift. In fact, it was entirely possible that the new paradigm would suffer from anomalies the old paradigm might have explained. Because of this, Kuhn thought there was never progress toward a Truth; rather, we simply replaced one idea that did not work with another, until that idea too needed replacing, and so on. This contradicted sharply with the logical positivists and Popper (and the new atheists) in that they all thought science could get at truth (or closer to truth, in Popper's case) if it was simply done long enough.

But what do all these terms mean? We have the short definitions for most of Kuhn's terms, but not the true essence of what Kuhn wants to get across. Obviously pre-paradigmatic science is science without a paradigm, but how is that type of science different than science with a paradigm? What is pre-paradigmatic science? What then, exactly, are normal science and extraordinary science? What is the actual definition of an anomaly for Kuhn? And what is the crisis to which Kuhn refers? We'll go over the terms in the order of the cycle Kuhn illustrates.

Pre-paradigmatic science is the time when all facts seem potentially valid – none are simply dismissed because they conflict with the paradigm. There is no guiding principle that makes one theory more valid than another. Imagine we are considering a paradigm for how fish breathe underwater, and we have no paradigm at this time. One may argue that fish can breathe water because they have gills, and the gills filter air. That would be considered a good theory. Someone else might argue that fish inhale water and their bodies have a way of drinking the excess water by sending it to the stomach while the air goes to their lung. That theory would also be good. Absent a paradigm explaining how fish breathe, both theories would be equally valid. In pre-paradigmatic science each school of thought discovers its own set of facts and interprets them on its own, independent of others working on the same overall idea. No one shares notes or compares findings, and in general this type of science is not very organized because there is no universal way of thinking to which all scientists in a field would adhere. The key difference between a good theory and a paradigm is that a good theory is just that – a theory. It is not universally held to be true. A paradigm, on the other hand, shapes and shadows all other scientific research within its field. All research done on fish, in our current example, would assume the truth of how fish breath based on the current paradigm. Further, there would also be the language barrier. A French speaking scientist might be working on the same thing on which an English speaking scientist is working, but neither might know what the other was doing because they would not be publishing their works in other languages yet. It is only after a paradigm has been established that this relatively collaboration-free type of science is left behind.

Once the paradigm is established, we have normal science. Normal science is "research based firmly off one or more past scientific achievements; achievements that some particular scientific community acknowledges for a time supplying the foundation for its further practice."[5]Normal science revolves around five "Ps," Promise, Precision, Prediction, Puzzle, and Puzzle solving. Promise refers to the promise that the paradigm can properly guide research. Precision leads to determining significant facts. Prediction refers to matching facts with theory. Puzzle is a special category of problems that can serve to test the ingenuity or skill in solution. Puzzle solving is simply articulating the paradigm. Under normal science, knowledge is pooled and collected among different scientists. When doing normal science, the paradigm tells scientists what result to expect. Should scientists get a result different than what the paradigm predicts, it is assumed that scientists are getting the result wrong, rather than that the paradigm might be wrong.

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[5]Kuhn, Thomas S. *The Structure of Scientific Revolutions,*. Chicago: University of Chicago, 1970. 10. Print.

Should scientists continue to get the same “wrong” result, this causes an anomaly within the paradigm. The structure of discovery of an anomaly according to Kuhn is 1) recognition of an anomaly (after all, getting a result different than the paradigm predicts could simply be just an error in the experiment), 2) pursuing the anomaly to determine if it is truly an anomaly, and finally, 3) adjusting the paradigm. Paradigms are never thrown out over a few anomalies. Rather, they are adjusted. Think again of astronomy, and the strange orbits of the planets in a geocentric universe. Rather than throw out the geocentric model, scientists came up with the idea of an epicycle – that the planets revolve in a circle while orbiting around the earth. Of normal science, Kuhn says, “In science… novelty emerges only with difficulty, manifested by resistance, against a background provided by expectation.”[6]

Next, the crisis occurs when anomalies have piled up too high and the current paradigm can no longer function. Scientists must then start trying to come up with a new paradigm, resulting in a wide range of scientific theories to account for the data. This scientific research for a new paradigm is extraordinary science. Kuhn writes, “The emergence of new theories demands large-scale paradigm destruction and major shifts in the problems and techniques of normal science, often preceded by a period of pronounced professional insecurity.”[7] The professional insecurity is understandable. Consider if you, the reader, spent the vast majority of your career basing all your decisions on a single, overarching theory. Imagine further that you were one of this theory’s great proponents. Imagine that now this theory you spent your entire career either under, or even defending, is slowly being abandoned for a new theory. It might cause some insecurity.

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[6]Ibid. p.64.

[7] Ibid. p. 67

Just to give some context, here are two examples. If you were a teacher, imagine you always thought you were educating the new generations and teaching them to think for themselves so they would be better citizens. Imagine now that that theory of pedagogy is being abandoned in favor of the theory that teachers are actually brainwashing students for the benefit of the people in power, and teaching them to just accept what they hear without questioning, making them better followers. Second, imagine you were a lawyer who always believed you were fighting for justice. Say you wrote many papers about how the law is impartial and fair. Now imagine that theory is being replaced by a theory that the law is really just a sword and shield for those with money to defend their interests and oppress those without the funds to hire lawyers and defend themselves, legally, from those in power. These examples are not perfect parallels, but they should serve to give a little more context to a non-scientist just how important the underlying theory for all the work these scientists do is to them.

In fact, this insecurity over a paradigm shift accounts for much of the resistance to changing the paradigm. Scientists of the old theory will often refuse to acknowledge the validity of the new theory, regardless of the evidence. Oftentimes, the current generation of scientists has to die before the old paradigm can be uprooted. On this note, Kuhn directly clashes with Popper. Whereas Popper believed old theories should be thrown out once they appear wrong, Kuhn says this is not at all what happens. Modifications are made to the paradigm rather than throwing out the entire paradigm, similar to how Quine would argue that one can change one belief within their web of beliefs without throwing out the whole web. Also, even when the old paradigm is rejected, it is not done away with until a new paradigm is ready to take its place. Once a paradigm is established, there will never be a return to pre-paradigmatic science, according to Kuhn.

When this crisis occurs it causes a breakdown in normal science. There are three possibilities of what can happen. Either normal scientists can ignore the anomaly, the current paradigm can be modified to account for the anomaly, or a new paradigm replaces the old one, thus solving the anomaly. Kuhn says that is not progress in any tangible sense. It's just one paradigm replacing another – just one way of doing science replacing another. Kuhn says they are "*non-cumulative* development episodes in which an older paradigm is replaced in whole or in part by an incompatible new one".[8] (emphasis added.) For Kuhn, it is not the world that defines the paradigm but the paradigm that defines the world.

Finally, Kuhn attempts to explain why so many people seem to think that science actually does progress. Kuhn says, "Both scientists and laymen take much of their image of creative scientific activity from an authoritative source that systematically disguises – partly for important functional reasons – the existence and significance of scientific revolutions."[9] This source Kuhn refers to is the textbook tradition. In the textbook tradition, scientific knowledge is an accumulation of facts that theories explain. But for Kuhn, facts and theories emerge together, theories are not made after considering the facts.

How then, would Kuhn respond to the implications drawn from the comments made by the new atheists we saw earlier? First, Harris implied that science progressed and moved forwards – in other words, it continually advanced. Kuhn did not. Kuhn

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[8]Ibid. p. 92.

[9]Ibid. p. 136.

argued that science does not move forward toward any goal. Rather, science is not even progress (for to progress, one has to have something to progress toward). Rather, science is just one paradigm replacing another. There is no fundamental progress. It may even be possible to go back to an old paradigm after further research has been discovered. These possibilities of going back to old paradigms, and the possibility that new paradigms will have problems the old paradigms did not, are sufficient evidence for Kuhn to prove that science does not move forward in any tangible sense, it merely moves. One might argue in response to Kuhn that we have cures for diseases, like polio, that we did not have before, and surely this is progress. Kuhn would likely argue that in creating cures for these diseases perhaps we are causing new diseases by these very cures. For example, the overuse of antibiotics is causing strains of diseases that are resistant to antibiotics, and are thus more deadly than their previous iterations. So even though we seemed to progress by creating antibiotics, now our diseases can resist antibiotics. Soon we may see all diseases resist antibiotics and we may be either right where we started or be even worse off than before.

Second, Hitchens implied that we know things for sure now that we did not know before. He also argues that ancient times were a period of little real knowledge. Kuhn would surely think it silly to think we can know anything for sure. Kuhn would argue that we knew for sure the earth was at the center of the universe, until we knew for sure it wasn't. There is nothing unique about our present time that proves that this time, unlike all the other times, we now understand the universe perfectly. In fact, the implications of Hitchens's comment are not only unlikely, but logically impossible. We cannot know today what we will discover tomorrow. Thus, we cannot (for certain) say today that we will never find anything tomorrow that proves false what we believed today. Even though Hitchens says he himself doesn't believe in faith, it does seem to take a certain kind of faith of its own to trust that modern science explains the universe for sure. After all the paradigms that have been adopted and replaced throughout history, to believe that now we have arrived at the end of all paradigms, and we will replace them no more, for no reason, seems a blind faith of its own. After all, scientists of the 1700s likely could have thought the same thing if they compared their knowledge to scientists of the 700s.

Third, Dawkins said that atheists do not have faith (and by logical extension since he sees himself as an atheistic scientist) scientists do not need faith. While Kuhn would agree that scientists would not need faith, he would certainly argue that those like Dawkins and Hitchens, who believe that science can provide actual answers, have faith in science whether they acknowledge it or not. Scientific "truths" have been come and gone so many times, clinging to the idea that eventually science will figure it all out does indeed require a great deal of faith.

Finally, Dennett argued that good hard evidence is better than faith. Since Dennett does not have faith in religion but does believe in science, it is seems he believes that science has good hard evidence. While Kuhn would agree that science does provide evidence, and from evidence it provides facts, Kuhn would disagree that "good hard evidence" is ever really "good" or "hard." The evidence is always open to interpretation, and in fact is often defined by that very interpretation. Consider the burning cloth from before. We all saw the cloth burn, but why it burned was disputed. In fact, we could even debate the fact that the cloth burned at all – we might have hallucinated. We would thus have to scientifically prove that our senses are reliable in this instance. But how could we prove our senses were reliable without an appeal to those very senses? We'd be required to assume the conclusion (that our senses were accurate) to arrive at the evidence for the conclusion (that our senses are accurate). Thus, there is no "good hard evidence" in science of the type Dennett would like.

While Kuhn could have answered these responses, he did have others he felt (wrongly) that required him to redefine his original theories. Well after writing *The Structure of the Scientific Revolutions*, Kuhn was challenged by other scientists, such as Dudley Shapere, Karl Popper, and Stephen Toulmin, on his views. Shapere argued that Kuhn's idea of the paradigm was too vague and could not function as any real theory. He further argued that the paradigm was relative, could be pretty much anything, and could not be nailed down. Shapere also said that the idea of a paradigm was tethered to a community belief, not reason.

Later, at the London Colloquium in 1965, Kuhn's beliefs were criticized by Karl Popper, John Watkins, and Stephen Toulmin. Popper argued that one conducting "normal science" was an unfortunate wretch – someone to be pitied. The normal scientist "accepts the ruling dogma of the day, who does not wish to challenge it, and who accepts a new revolutionary theory only if almost everybody else is ready to accept it – if it becomes fashionable by a kind of bandwagon effect."[10]Watkins argued that normal science was "a state of affairs in which critical science had contracted into defensive metaphysics."[11]Toulmin further argued that the problem with critical science is always open to challenge the intellectual authority of the fundamental scheme they're working

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[10]*Criticism and the Growth of Knowledge: Proceedings of the International Colloquium in the Philosophy of Science, London, 1965*. Ed. ImreLakatos and Alan Musgrave.Vol. 4. London: Cambridge U.P, 1970. 52. Print.

[11] Ibid. p.28

with. He said of critical science that it gives itself a "permanent right to challenge this authority…being one of the things which…marks off and intellectual procedure as being 'scientific' at all."[12]

The truly ironic thing about all of the scientists who criticized Kuhn is that all of them seemed to fundamentally misunderstand Kuhn's argument. Dudley Shapere's "criticism" of Kuhn's argument is more of a reiteration of Kuhn's own work than a critical analysis. Rather than pointing out flaws in Kuhn's reasoning, as he likely intended, Shapere merely clearly identified Kuhn's conclusions about science. Shapere's statements likely only seemed like criticisms of Kuhn's arguments because most scientists of the time (and the current time) would have thought such conclusions absurd. To explain this, if Kuhn argued that Y causes X, Shapere's "criticism" would be along the lines of saying, "Kuhn argues that *Y causes X* and thus cannot be right" rather than explaining *why* Y cannot cause X. Scientists of the day would not have expected Shapere to explain why Y could not cause X, because none of them believed Y could cause X.

Karl Popper, while his ideas on science as falsification may have merit, advocated a thoroughly unrealistic view of how science should be done. Popper's theory of falsification recommended that scientists make bold claims about the world then try their best to disprove their own claims. Consider, if a scientist today made a bold claim that we can travel to distant galaxies through wormholes, would he be likely to get funding to attempt to create a wormhole and then prove we cannot travel through it? Probably not. Would his theory be accepted as true until it was disproven? Of course not. The problem with Popper's criticism of Kuhn was that Popper's theory of how science should be done

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[12]Ibid. p.40.

was completely impractical. Popper's criticism of Kuhn boiled down to this: Kuhn's theory of science was not Popper's, thus it was wrong.

Toulmin's argument against Kuhn was perhaps even more invalid than Popper's. Toulmin seemed to be arguing that any science within a certain field could never challenge fundamental assumptions of that field. By Toulmin's reasoning, Copernicus should have never been allowed to challenge the fundamental assumption of the geocentric universe.

All of the arguments Kuhn's critics made against Kuhn's theory had huge problems, but instead of sticking to his initial theory, which very few people in the scientific community seemed to be willing to accept or even attempt to understand, Kuhn reclassified his paradigms to exemplars, his normal science to the disciplinary matrix, and added a substantial postscript that muted the impact of his own work. Essentially, his changes make his own work more difficult to understand, less applicable to scientific practice, and generally less insightful than they were before. Ironically, it was the collective assumptions of the scientific community as a whole that shaped how Kuhn viewed their arguments. Had only one or two scientists challenged Kuhn's work, he would have likely defended his initial beliefs until he died. The fact that Kuhn felt it necessary to redefine his own works to fit with the rest of science seems to be just further evidence that Kuhn was right the first time. Rather than follow Kuhn's surrender to bad arguments, we will examine the emerging work between fossil fuels and abiotic oil along Kuhn's original theory of the paradigm.

CHAPTER THREE

Background Science for Fossil Fuel Theory and Abiotic Oil Theory

This chapter is dedicated to providing background information on the basic scientific assumptions behind both fossil fuel theory and abiotic oil theory – information that is uncontested by either theory. It is primarily meant to provide important information for the layperson reading this paper to better understand the fundamental disagreement between the two theories. This chapter will cover the following topics: 1) what exactly is petroleum, and 2) how is oil refined? For the reader who already knows the answer to these two questions, he or she may want to simply skip ahead to Chapter Four. For the reader who does not know the answers to these questions, it will be important for understanding the rest of this paper to read this chapter.

So, what exactly is petroleum? What is meant by "oil"? The first thing to know is that there are different names for this type of oil, such as petroleum and crude oil. Both are names for the type of oil that comes out of the ground (the black liquid often associated with many people's idea on oil).[1]Crude oil contains various types of hydrocarbons, which "are molecules that contain hydrogen and carbon and come in various lengths and structures, from straight chains to branching chains to rings."[2] Hydrocarbons contain lots of energy, and this can be harnessed when refining crude oil into making various different things – from gasoline to plastic. Methane is the smallest

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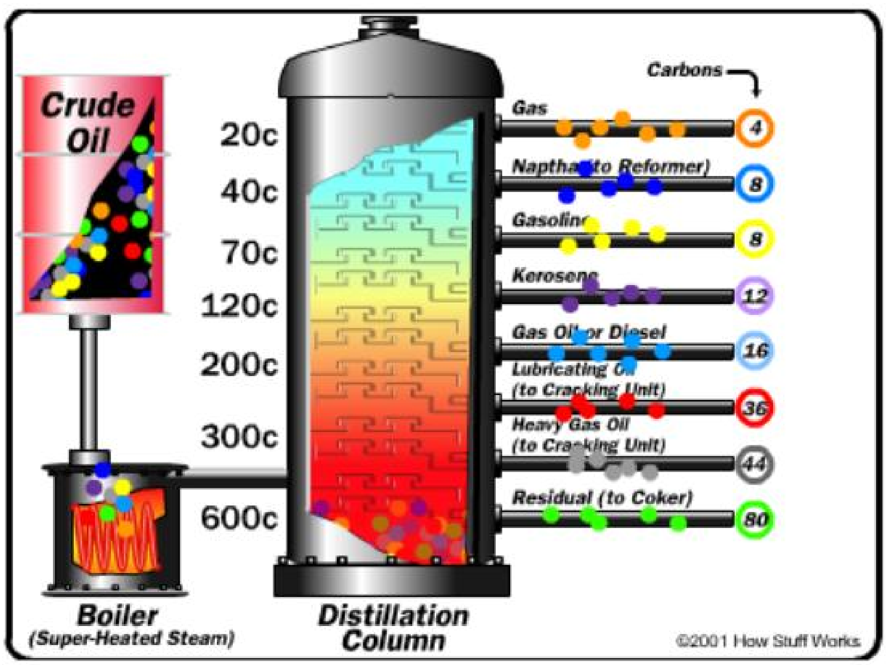
[1]Freudenrich, Craig C. "How Oil Refining Works." *HowStuffWorks*.N.p.,n.d. Web. 18 Dec. 2012.Craig Freudenrich, Ph.D., is a freelance science writer and former senior editor at HowStuffWorks. He earned a B.A. in biology from West Virginia University and a Ph.D. in physiology from the University of Pittsburgh School of Medicine before completing eight years of postdoctoral research at Duke University Medical Center.

[2] Ibid

hydrocarbon, and is lighter than air.[3] Some of the various hydrocarbons that can be found in crude oil are: methane, ethane, propane, butane, isobutene, pentane, and hexane.[4]

Next, how is oil refined? While refining oil has many different parts, here we will only focus on the basic process that the reader should be familiar with for the rest of the paper's purpose. The various hydrocarbons in crude oil have varying boiling points based on their molecular chain length. Longer chains have higher boiling points. One part of the refining process then, is distillation, which is used to separate the various hydrocarbons into their component parts. The following picture serves as an example of what this process looks like:[5]



It is also important to know how many of the hydrocarbons from one barrel of crude oil can be used. Crude oil is used for far more than just gasoline for one's car.

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[3] Ibid.

[4] Ibid.

[5] Ibid.

Craig Freudenrich explains the various types of substances that can be gained by distilling crude oil:

> **Petroleum gas** - used for heating, cooking, making plastics (chains of 1 to 4 carbon atoms).**Gasoline** (chains of5 to 12 carbon atoms; boiling range: 104 to 401 degrees Fahrenheit / 40 to 205 degrees Celsius) **Kerosene -** used as fuel for jet engines and tractors; starting material for making other products (chains of 10 to 18 carbons; boiling range: 350 to 617 degrees Fahrenheit / 175 to 325 degrees Celsius), **Gas oil** or **Diesel distillate -** used for diesel fuel and heating oil; starting material for making other products (chains of alkanes containing 12 or more carbon atoms; boiling range: 482 to 662 degrees Fahrenheit / 250 to 350 degrees Celsius). **Lubricating oil -** used for motor oil, grease, other lubricants (chains of 25 – 50 carbon atoms; boiling range: 572 to 700 degrees Fahrenheit / 300 to 370 degrees Celsius). **Heavy gas** or **Fuel oil -** used for industrial fuel; starting material for making other products (chains of 20 to 70 carbon atoms; boiling range: 700 to 1112 degrees Fahrenheit / 370 to 600 degrees Celsius). **Residuals -** coke, asphalt, tar, waxes; starting material for making other products (multiple-ringed compounds with 70 or more carbon atoms; boiling range: greater than 1112 degrees Fahrenheit / 600 degrees Celsius).[6]

Thus it should be clear that crude oil is the initial source of a great many different materials that people use on a daily basis. This distillation method is a relatively old way of breaking up the various hydrocarbons. Newer methods, such as Chemical Processing, allow the refineries to combine or break down what is produced through distillation to create other compounds. So, for example, in a gasoline shortage, refineries could break down Residuals further to make more gasoline from each individual barrel of crude oil.[7]

Petroleum is a combination of hydrocarbons, and it is refined using a distillation method to separate the various hydrocarbons bound up in the petroleum when it is extracted.

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[6]Ibid.

[7]Ibid.

CHAPTER FOUR

Fossil Fuel Theory

Dead dinosaurs, decomposed plants, fossils compressed by pressure – all are elements that have led to the creation of fossil fuels, so says fossil fuel theory. While this paper does intend to discuss the merits and demerits of both fossil fuel theory and abiotic theory, it will spend more time on abiotic theory than fossil fuel theory. The main reason for this is that it is assumed the reader has a rudimentary understanding of fossil fuel theory, whereas it is also assumed the reader has either never heard of abiotic theory, or has little to no understanding of it. Also, fossil fuel theory is very well established in the Western world, which is where it is assumed this paper will primarily be read. Thus, it will be important to lay out in detail the argument behind abiotic theory more thoroughly. As with Chapter Three, those who have a good understanding of fossil fuel theory can skip this chapter. Readers familiar with the theory, but who have not studied the theory should still read this chapter, as it does provide some detail.

According to fossil fuel theory, the three primary fossil fuels used today are coal, natural gas, and oil.[1]These fossil fuels are formed "only after organic material is broken down over millions of years in an anaerobic environment, one with little or no oxygen… The fossil fuels we burn today in our vehicles, homes, industries, and power plants were formed from the tissues of organisms that lived 100-500 million years ago."[2]As for how these dead organisms become hydrocarbons, fossil fuel theory states, "When organisms

[1]Withgott, Jay, and Matthew Laposata. *Essential Environment: The Science behind the Stories*. Upper Saddle River, NJ.: Pearson, 2012. Print.

[2] Ibid.

were buried quickly in anaerobic sediments after death, chemical energy in their tissues became concentrated as the tissues decomposed and their hydrocarbon compounds were chemically altered amid heat and compression."[3]As for examples of how this might occur, Withgott and Laposata write, "Fossil fuels begin to form when organisms die and end up in oxygen-poor conditions, such as when trees fall into lakes and are buried by sediment, or when phytoplankton and zooplankton drift to the seafloor and are buried."[4] For organic material under higher pressure, they write, "Organic matter that undergoes slow anaerobic decomposition deep under sediments forms kerogen. Geothermal heating then acts on kerogen to create crude oil and natural gas."[5]For how the specific fossil fuels are formed, they add, "Oil and gas come to reside in porous rock layers beneath dense, impervious layers. Coal is formed when plant matter is compacted so tightly that there is little decomposition."[6]To summarize how crude oil is formed – the hydrocarbon we are primarily concerned with in this paper – Withgott and Laposata summarize, "Both natural gas and oil have formed from organic material (especially dead plankton) that drifted down through coastal marine waters millions of years ago and was buried in sediments on the ocean floor. This organic material was transformed by time, heat, and pressure into today's natural gas and crude oil."[7]

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[3]Ibid.

[4] Ibid.

[5] Ibid.

[6] Ibid.

[7] Ibid.

What commonly accompanies fossil fuel theory is the fear that the world is running out of oil, and that it will run out soon.[8] One implication is inevitable if the fossil fuel theory is true: if we are extracting oil faster than it can be replenished (something all fossil fuel theorists hold to be true), we will eventually run out of oil to extract. Technically, oil is renewable in the fossil fuel theory – after all dead plankton are still drifting to the bottoms of oceans and being buried, which will eventually lead to more oil. What fossil fuel theorists are really arguing is that oil does not replenish itself nearly fast enough to be considered renewable in a practical context.

There is another important factor to remember: no one really *knows* how much extractable petroleum is buried in the earth. Scientists make guesses of varying accuracy to when peak oil (the time at which petroleum production will peak and then decline) will occur, but so long as no one knows how much oil is really there to be extracted, no one can know with certainty when peak oil will occur – though if fossil fuel theory is true it *can* be known that peak oil *will* occur at some point, whether we can predict that point or not. Regardless, the point of this paper is not to analyze where the dates predicted to mark peak oil are accurate or not, it is sufficient to simply say they exist, and that if fossil fuel theory is true, then peak oil will inevitably occur.

In this chapter we have covered the basic tenant behind fossil fuel theory – things die, get covered in sediment at various depths within the earth surface, decompose and end up as hydrocarbons which will form petroleum. We have also mentioned the prediction of peak oil briefly. Again, as fossil fuel theory is already established, our time is better spent here covering its flaws and its emerging competitor.

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[8] Hubbert, M. K. "Energy from Fossil Fuels." *Science* 109.2823 (1949): 103-09. Print.

CHAPTER FIVE

Abiotic Oil Theory

Also known as abiogenic oil theory, or the R-U theory, abiotic oil theory was originally proposed in Russia, and has been established in the East for several decades. It was quickly dismissed in the West since the West already had its own paradigm regarding oil theory. Recently, however, a new study published in the Proceedings of the National Academy of Science (PNAS) has provided crucial legitimacy to the theory in the United States. To give a bit of context, PNAS is an extremely authoritative scientific journal in the United States, usually focusing on publishing theories that give a breakthrough in their fields. In 2002, a new paper was published in PNAS titled, "The evolution of multicomponent systems at high pressures: VI. The thermodynamic stability of the hydrogen–carbon system: The genesis of hydrocarbons and the origin of petroleum." The contributors were J.F. Kenney, V.A. Kutcherov, N.A. Bendellani, and V.A. Alekseev.[1]This study of abiotic oil not only seems to prove that the abiotic theory of oil is true, but that the fossil fuel theory is *impossible*. This chapter will go over the experiment conducted by these four scientists and published in PNAS. Hereafter, the experiment detailed in this article of PNAS will be referred to simply as the "abiotic experiment." Also, all marked figures are numbered as they are in the original article for the convenience of the reader, they have not been renumbered.

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[1] J.F. Kenney, V.A. Kutcherov, N.A. Bendellani, and V.A. Alekseev, "The Evolution of Multicomponent Systems at High Pressures: VI. The Thermodynamic Stability of the Hydrogen-Carbon System: The Genesis of Hydrocarbons and the Origin of Petroleum," PNAS 99, 10976-10981 (August 20, 2002). http://www.pnas.org/content/99/17/10976.full.pdf

Introduction

The quotation dealing with the setup of the experiment is long and somewhat technical. As such, in the text of this paper I have pared it down for the layperson, but the entire quotation can be found in the appendix. The appendix will also provide the entire quotation of the sections dealing with implications and results which I have shortened a bit from their originals. For simplicity, the quotes which were cut down will be marked I, II, or III and will correspond to those same symbols in the appendix. The appendix quotes will be bolded to indicate which part of the text I copied for the paper itself – unbolded parts are parts of the quotation I did not copy over. I will be providing commentary throughout this section to explain the quotes themselves as well. Before we begin, note that H–C is an abbreviation of hydrogen–carbon (Kenney et al. will reference this many times).

The Set Up

Kenney et al. write:

> Because the H–C system typical of petroleum is generated at high pressures and exists only as a metastable mélange at laboratory pressures, special high-pressure apparatus has been designed that permits investigations at pressures to 50 kbar and temperatures to 1,500°C, and which also allows rapid cooling while maintaining high pressures… Experiments to demonstrate the high-pressure genesis of petroleum hydrocarbons have been carried out using only 99.9% pure solid iron oxide, FeO, and marble, $CaCO_3$, wet with triple-distilled water. There were no biotic compounds or hydrocarbons admitted to the reaction chamber… Pressure in the reaction cell… of volume 0.6 cm^3 was measured by a pressure gauge calibrated using data of the phase transitions of Bi, Tl, and PbTe. The cell was heated by a cylindrical graphite heater; its temperature was measured using a chromel-alumel thermocouple and was regulated within the range ±5°C. Both stainless steel and platinum reaction cells were used; all were constructed to prevent contamination by air and provide impermeability during and after each experimental run.[I,2]

[2] Ibid. p.10980

For the set-up, Kenney et al. explain what their device is meant to do and how it is controlled. The first part basically says the abiotic experiment will use a device capable of measuring pressures up to 50kbar and temperatures to 1,500°C. One bar of pressure is roughly equal to one atmosphere of pressure (for those who are more familiar with that measurement). Thus one kbar of pressure is roughly equal to 1000 atmospheres of pressure, and 50 kbar are roughly about 50,000 atmospheres of pressure. As a note, one bar actually equals0.9869 atmospheres, so 50kbar does not precisely equal 50,000 atmospheres of pressure, but it should give a general sense of how much pressure the chamber is meant to deal with for those less familiar with kbar measurements. Also, 1500°Cis equal to 2732°F. After Kenney et al. explain what environments the device can reproduce, they then explain how the device will prevent interference from outside sources during the experiment. Especially important is that no biotic compounds or other hydrocarbons were admitted into the chamber. This is so important because the point of the experiment is to prove the hypothesis that the hydrocarbons needed to make oil can be produced *absent* biotic compounds (compounds like dead zooplankton on the ocean floor). Also, obviously if hydrocarbons from outside the experiment got into the device it would invalidate an experiment designed to produce hydrocarbons from within.

The Procedure

Kenney et al. write:

> The reaction cell was brought from 1 bar to 50 kbar gradually at a rate of 2 kbar/min and from room temperature to the elevated temperatures of investigation at the rate of 100 K/min. The cell and reaction chamber were held for at least 1 h at each temperature for which measurements were taken to allow the H–C system to come to thermodynamic equilibrium. The samples thereafter were quenched rapidly at the rate of 700°C/sec to 50°C and from 50°C to room temperature over several minutes while maintaining the high pressure of investigation. The pressure was then reduced gradually to 1 bar at the rate of 1 kbar/min. The reaction cell

> was then heated gently to desorb the hydrocarbons for mass spectrometer analysis using an HI-120 1B mass spectrometer equipped with an automatic system of computerized spectrum registration. A specially designed high-temperature gas probe allowed sampling the cell while maintaining its internal pressure.[3]

This section is relatively straightforward. The scientists started the device at a low pressure and temperature, gradually raised both, while holding for at least one hour at each temperature where measurements were taken, followed by rapidly cooling the chamber and decreasing the pressure, concluding with analysis of the results. The only other note that I'll make here is that 100K/min is the same rate as 100°C/min.

The Results

Kenney et al. write:

> At pressures below 10 kbar, no hydrocarbons heavier than methane were present. Hydrocarbon molecules began to evolve above 30 kbar. At 50 kbar and at the temperature of 1,500°C, the system spontaneously evolved methane, ethane, n-propane, 2-methylpropane, 2,2-dimethylpropane, n-butane, 2-methylbutane, n-pentane, 2-methylpentane, n-hexane, and n-alkanes through $C_{10}H_{22}$, ethene, n-propane, n-butane, and n-pentene in distributions characteristic of natural petroleum. The cumulative abundances of the subset of evolved hydrocarbons consisting of methane and n-alkanes through n-C_6H_{14} are shown in Fig. 3 as functions of temperature. Methane (on the right scale) is present and of abundance ≈1 order of magnitude greater than any single component of the heavier n-alkanes, although as a minor component of the total H–C system. That the extent of hydrocarbon evolution becomes relatively stable as a function of temperature above ≈900°C, both for the absolute abundance of the individual hydrocarbon species as well as for their relative abundances, argues that the distributions observed represent thermodynamic equilibrium for the H–C system. That the evolved hydrocarbons remain stable over a range of temperatures increasing by more than 300 K demonstrates the third prediction of the theoretical analysis: Hydrocarbon molecules heavier than methane do not decompose with increasing temperature in the high-pressure regime of their genesis.[4]

Figure 3 (as referenced in the quotation) is on the following page:

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[3] Ibid. p. 10980

[4] Ibid. p. 10980-10981

Figure 3[5]:

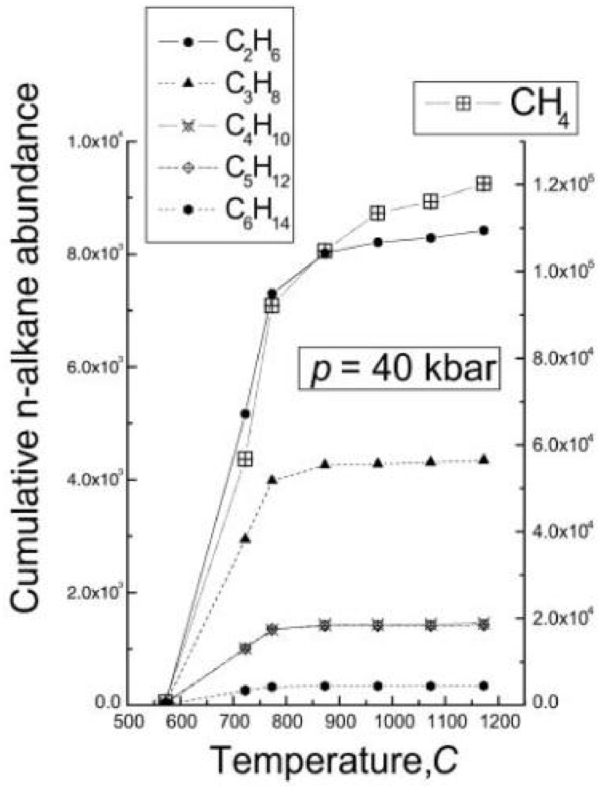

Fig. 3. Cumulative abundances of *n*-alkanes through *n*-C_6H_{14} on left ordinate, methane abundance on right, as functions of temperature at the pressure of 40 kbar. (Scales are in ppm.)

One of the most important things to note from the results is in the first sentence: "At pressures below 10 kbar, no hydrocarbons heavier than methane were present." Possibly the second most important result is the second sentence: "Hydrocarbon molecules began to evolve above 30 kbar." Only methane evolved on its own at a pressure less than 10 kbar. Other hydrocarbons (which, remember, are required to make crude oil) did not occur until pressure went above 30 kbar. One implication (which will

[5] Ibid. p.10980

be covered in more detail later) is that crude oil *cannot* be formed in pressures less than 10 kbar.

As a note, for the continental crust, 1 kbar of pressure is approximately equal to 3.64km of depth. For the oceanic lithosphere, 1 kbar of pressure is approximately equal to 3.19 kilometers of depth.[6]

The Implications

Kenney et al. write:

> The pressure of 30 kbar, at which the theoretical analyses… predicts that the H–C system must evolve ethane and heavier hydrocarbon compounds, corresponds to a depth of more than 100 km. The results of the theoretical analysis shown in Fig. 2 clearly establish that the evolution of the molecular components of natural petroleum occur at depth *at least* as great as those of the mantle of the Earth, as shown graphically in Fig. 4, in which are represented the thermal and pressure lapse rates in the depths of the Earth. As noted, the theoretical analyses reported in section 4 describe the high-pressure evolution of hydrocarbons under the *most favorable* chemical conditions… Furthermore, the multicomponent system analyzed theoretically included no oxidizing reagents that would compete with hydrogen for both the carbon and any free hydrogen. The theoretical analysis assumed also the possibility of at least a metastable presence of hydrogen. Therefore, the theoretical results must be considered as the determination of *minimum* boundary conditions for the genesis of hydrocarbons. In short, the genesis of natural petroleum must occur at depths not less than ≈100 km, well into the mantle of the Earth. The experimental observations reported…confirm theoretical predictions…and demonstrate how, under high pressures, hydrogen combines with available carbon to produce heavy hydrocarbon compounds in the geochemical environment of the depths of the Earth.[II,7]

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[6]Brown, G. C., C. J. Hawkesworth, and R. C. L. Wilson. *Understanding the Earth*. Cambridge England: Cambridge UP, 1992. 228. Print.

[7] J.F. Kenney, V.A. Kutcherov, N.A. Bendellani, and V.A. Alekseev, "The Evolution of Multicomponent Systems at High Pressures: VI. The Thermodynamic Stability of the Hydrogen-Carbon System: The Genesis of Hydrocarbons and the Origin of Petroleum," PNAS 99, 10981 (August 20, 2002). http://www.pnas.org/content/99/17/10976.full.pdf

Figure 2[8] and figure 4[9] (as referenced by the above section) are reproduced below.

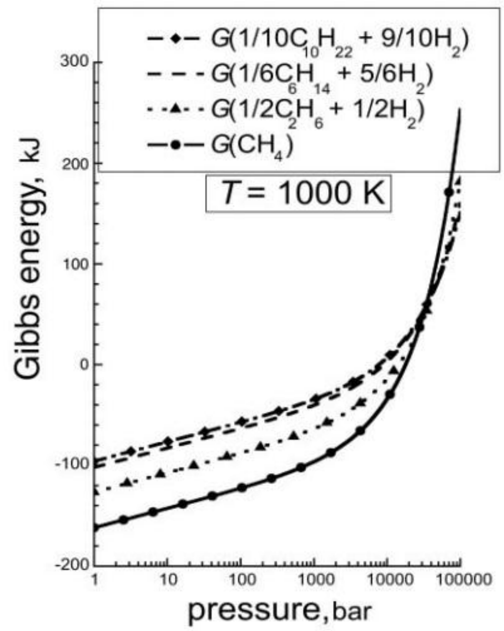

Fig. 2. Gibbs energies of methane and of the H–C system $[(1/n)C_nH_{2n+2} + (n-1)/nH_2]$.

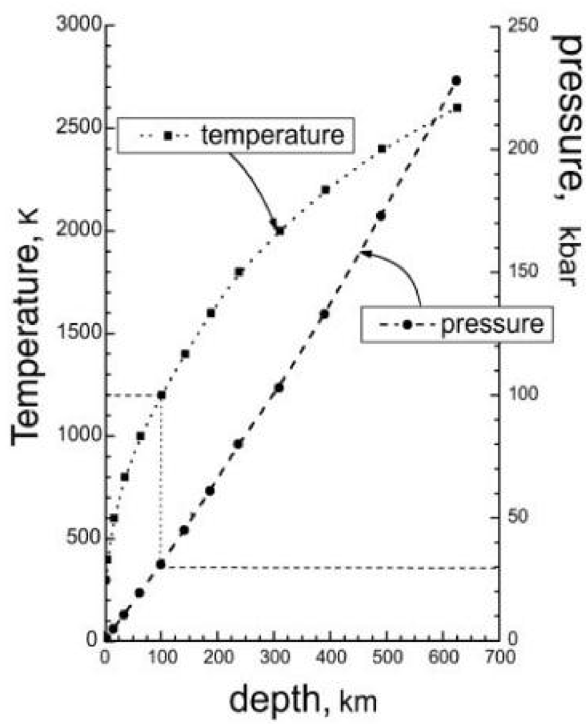

Fig. 4. Pressure and temperature in the depths of the Earth.

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8 Ibid. p. 10979

Kenney et al. explain specifically the results shown by figure 2, "These results demonstrate clearly that all hydrocarbon molecules are unstable chemically and thermodynamically relative to methane at pressures less than ≈25 kbar for the lightest, ethane, and 40 kbar for the heaviest n-alkane shown, decane."

Here we see the full implications of the experiment laid out. Kenney et al. say their results show that 100km of depth in the earth (within its mantle) is the *minimum* depth required to produce hydrocarbons necessary for oil to be produced *under ideal conditions*. Without ideal conditions, the depth will likely need to be even deeper.

Validation of Earlier Experiments and Final Analysis

Kenney et al. write:

> The results of this theoretical analysis are strongly consistent with those developed previously by Chekaliuk and Kenney(29–32)using less accurate formal tools. The analysis of the H–C system at high pressures and temperatures has been impeded previously by the absence of reliable equations of state that could describe a chemically reactive, multicomponent system at densities higher than such of its normal liquid state in ordinary laboratory conditions and at high temperatures. The first analyses used the (plainly inadequate) Tait equation (33)**;**later was used the quantum mechanical Law of Corresponding States(34)**;**more recently has been applied the single-fluid model of the SPHCT(31, 32).Nonetheless, all analyses of the chemical stability of the H–C system have shown results that are qualitatively identical and quantitatively very similar: all show that hydrocarbons heavier than methane cannot evolve spontaneously at pressures below 20–30 kbar. The H–C system does not spontaneously evolve heavy hydrocarbons at pressures less than ≈30 kbar, even in the most favorable thermodynamic environment. The H–C system evolves hydrocarbons under pressures found in the mantle of the Earth and at temperatures consistent with that environment.[III,10]

In this final section detailing their experiment, the authors note that previous experiments attempting to prove similar outcomes had problems caused by inadequate

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[9] Ibid. p. 10981
[10] Ibid. p. 10981

equipment that prevented their results from being as untainted as the abiotic experiment, however they all came to roughly the same conclusion – hydrocarbons heavier than methane *cannot* spontaneously evolve at pressures below 20-30 kbar, and heavy hydrocarbons cannot spontaneously evolve at pressures less than about 30 kbar.

Now that we've covered the abiotic experiment itself in detail, it is important to draw implications from the results. While we clearly stated that the abiotic experiment showed that heavy hydrocarbons cannot be formed spontaneously at pressures less than 30 kbar, and thus petroleum cannot be formed at pressures lower than 30 kbar, according to the abiotic experiment, there is much more that Kenney et al. had to say in their article about the fossil fuel theory. We will now look at problems – anomalies – that have been seen to occur in the fossil fuel theory.

CHAPTER SIX

Fossil Fuel Theory Anomalies

We've already seen some potential problems for the fossil fuel theory shown in the abiotic experiment covered in Chapter Five. There are also several more explicit problems facing the fossil fuel theory than simply the results of the abiotic experiment. Kenney et al. detail several of them, and we will cover many of those in this chapter.

We will start with a premise and work from there, rather than simply listing arguments. Kenney et al. explain the second law of thermodynamics as it applies to energy transfers (I have omitted the equations behind the reasoning and replaced them in the argument with [formula] or left them as the authors have abbreviated them, e.g. "(Eq. 1)". To see the actual formulas, please see the article itself referenced in footnote 37). Kenney et al. write:

> The second law states that the internal production of entropy is always positive for every spontaneous transformation. Therefore, the thermodynamic Affinity(Eq. 1)must always be positive, and the direction of evolution of any system must always obey the inequalities**:** [formula]. The inequalities in Eq. 2 express the irreversibility of spontaneous transitions and state that for a spontaneous evolution of a system from any state, A, to any other state, B, the free enthalpy of state B must be less than that of state A, and at no point between the two may the free enthalpy be greater than that of state A or less than that of state B. The sum of the products on the second line of inequality in Eq. 2, of the thermodynamic Affinities and the differential of the variables of extent,dǯρ**,**is always positive, and the circumstance for which the change of internal entropy is zero defines equilibrium, from which there is no spontaneous evolution. This is De Donder's inequality.[1]

In other words, the second law (of thermodynamics) states that in spontaneous transformations as energy is transferred from state A to state B, energy decreases, and it

[1] Ibid. p.10977

can never be greater than in state A or less than in state B in between the two states. For an analogous example, think of a battery in some appliance. State A is the battery at the charge it is at when the appliance is turned on, and state B is the charge the battery is at when the appliance is turned off. During that period of use, the battery will transfer its charge to the appliance. It is thus losing energy as the energy is transferred. Also note that the charge in the battery will never be greater than it is at state A (when the appliance is first turned on) nor less than that at state B (when the appliance is finally turned off). While the battery example is not a spontaneous transformation, it serves as a decent example of the second law.

So what does the second law have to do with causing anomalies in the fossil fuel theory? Kenney et al. further:

> Examination of the H–C–O system of oxidized carbon compounds establishes that the chemical potentials of almost all biotic compounds lie far below that of methane, the least energetic of the reduced hydrocarbon compounds, typically by several hundred kcal/mol**.** Although there exist biotic molecules of unusually high chemical potential such as β-carotene ($C_{40}H_{56}$), vitamin D ($C_{38}H_{44}O$), and some of the pheromone hormones, such compounds are relatively rare by abundance. They are produced by biological systems only when the producing entity is alive (and at formidable metabolic cost to the producing entity), and the production ceases with the death of the entity. Such compounds are not decomposition products of other biotic compounds and are labile and themselves decompose rapidly. For these foregoing reasons, such compounds cannot be considered relevant to the subject of the origin of natural petroleum.[2]

Here, Kenney et al. are saying that organic materials have very low chemical potentials, and almost all are below that of methane (the hydro-carbon with the lowest chemical potential). Only a few rare organic compounds have high chemical potentials, and they are rarely found in abundance in one spot. These high chemical potential biotic compounds can only be produced by living organisms at very high metabolic costs. They

[2] Ibid. p. 10977-10978

cannot be produced by dead things – *in other words, dead zooplankton* (as we saw in Chapter Four the fossil fuel theory suggested was a main source of oil) *could never decompose into even the lowest chemical potential hydrocarbon (methane) let alone hydrocarbons necessary to make petroleum*. Things of low chemical potential cannot result in things of high chemical potential – as described just previously when Kenney et al. described the second law of thermodynamics. All energy flows downhill, thus a higher chemical potential in compound A is needed to make compound B, which must have a lower chemical potential than compound A. Decaying organic material could never create hydrocarbons, and thus could never create petroleum, because the hydrocarbons needed to create petroleum have a *higher* chemical potential than dead biotic material.

In case the implication is not yet clear, remember that THE key tenant of the fossil fuel theory is that decaying organic material over time became hydrocarbons and thus petroleum. Here, Kenney et al. argue that by the second law of thermodynamics, and the very low chemical potentials of dead organisms, the key tenant of the fossil fuel theory is not only unlikely to be true, but is *scientifically impossible*.

In the event that this first argument is not enough to cause serious problems to the fossil fuel theory, Kenney et al. advance yet another argument backed by scientific study of hydrocarbons. Kenney et al. argue that all hydrocarbons, except methane, are unstable at low pressures regardless of the temperature and will inevitably break down. They write:

> The properties of the thermodynamic energy spectrum of the H–C and H–C–O systems, together with the constraints of the second law(Eq. 2)establish three crucial properties of natural petroleum:

> (i) The H–C system that constitutes natural petroleum is a metastable one in a very nonequilibrium state. At low pressures, all heavier hydrocarbon molecules are thermodynamically unstable against decomposition into methane and carbon, as similarly is diamond into graphite.
>
> (ii) Methane does not polymerize into heavy hydrocarbon molecules at low pressures at any temperature. Contrarily, increasing temperature (at low pressures) must increase the rate of decomposition of heavier hydrocarbons into methane and carbon.
>
> (iii) Any hydrocarbon compound generated at low pressures, heavier than methane, would be unstable and driven to the stable equilibrium state of methane and carbon. These conclusions have been demonstrated amply by a century of refinery engineering practice. The third conclusion has been demonstrated by many unsuccessful laboratory attempts to convert biotic molecules into hydrocarbons heavier than methane.
>
> The theoretical analyses reported here describe the high-pressure evolution of hydrocarbons under the most favorable chemical conditions. Therefore, although this analysis describes the thermodynamic stability of the H–C system, it does not explicitly do the same for the genesis of natural petroleum in the conditions of the depths of the Earth. The chemical conditions of the Earth, particularly near its surface, are oxidizing, not reducing; of the gases in the Earth's atmosphere and crust, hydrogen is significantly absent, and methane is a very minor constituent.[3]

This second argument against the fossil fuel theory is just as devastating as the first argument. The individual steps argue as follows: 1) at low pressures (think low depths in the earth – as in above the mantle) all heavier hydrocarbons are unstable and will break down into methane and carbon as time goes by; 2) methane does not turn back into heavy hydrocarbons at low pressures, thus, after heavy hydrocarbons break down into methane at low temperatures, they could not backtrack and become heavy hydrocarbons again, and if temperatures were hotter for some reason at a low pressure, it would simply increase the rate that heavy hydrocarbons devolved into methane; and 3) even if heavy hydrocarbons *could* be spontaneously made at low pressures (think 10 kbar), they would break down into methane. The impact to fossil fuel theory is that *even*

[3] Ibid. p.10978

if decomposing biotic compounds could result in heavy hydrocarbons (which it cannot), at the depths fossil fuel theory expects to find them, they would be unstable and would break down into methane and carbon – they would not combine into petroleum. Finally, the argument notes that all of this reasoning is under ideal conditions for heavy hydrocarbons to exist at low pressures. In realistic conditions, results of heavy hydrocarbons existing at low pressures are even worse for the fossil fuel theory.

Finally, not only do Kenney et al. attempt to prove that abiotic theory is correct and fossil fuel theory is false, they even argue that as early as the 19th century scientists already knew that the method the fossil fuel theory argues created natural petroleum was impossible. Even though those scientists did not know *how* natural petroleum was created, they knew how it was *not* created. Kenney et al. writes:

> The foregoing properties of natural petroleum and the effective prohibition by the second law of thermodynamics of its spontaneous genesis from highly oxidized biological molecules of low chemical potentials were clearly understood in the second half of the 19th century by chemists and thermodynamicists such as Berthelot and later confirmed by others including Sokolov, Biasson, and Mendeleev. However, the problem of how and in what regime of temperature and pressure hydrogen and carbon combine to form the particular H–C system manifested by natural petroleum remained. The resolution of this problem had to wait a century for the development of modern atomic and molecular theory, quantum statistical mechanics, and many-body theory. This problem now has been resolved theoretically by determination of the chemical potentials and the thermodynamic Affinity of the H–C system using modern quantum statistical mechanics and has also now been demonstrated experimentally with specially designed high-pressure apparatus.[4]

The implication is that not only is fossil fuel theory untrue, as early as the 19th century several scientists knew it could not possibly be true. The response has mostly been curt dismissals that the abiotic theory could be true (because it conflicts with the current paradigm).

[4] Ibid. p.10978

CHAPTER SEVEN

Abiotic Theory Anomalies

In the West, abiotic theory is mostly simply dismissed rather than engaged, and for many years this was possible. However, after 2002 and the abiotic experiment's publication in PNAS, it will become increasingly difficult for fossil fuel theorists to be able to legitimately dismiss abiotic theory. As a result of the many dismissals, there are fewer legitimate arguments against abiotic theory than there are against fossil fuel theory, but there are still some, though even these are usually laced with condescension from the authors. In this chapter we will examine one critic who provides some legitimate challenges to abiotic theory. UgoBardi, professor of chemistry at the University of Florence, Italy, criticizes abiotic oil.[1,2]

Bardi starts by saying what he will cover and what he will not cover. He writes:

> Normally, the discussion of abiotic oil oscillates between the scientifically arcane and the politically nasty. Even supposing that the political nastiness can be detected and removed, there remains the problem that the average non-specialist in petroleum geology can't hope to wade through the arcane scientific details of the theory (isotopic ratios, biomarkers, sedimentary layers and all that) without getting lost. Here, I will try to discuss the origin of oil without going into these details. I will do this by taking a more general approach. Supposing that the abiogenic theory is right, then what are the consequences for us and for the whole biosphere? If we find that the consequences do not correspond to what we see, then we can safely drop the abiotic theory without the need of worrying about having to take a course in advanced geology. We may also find that the consequences are so small as to be irrelevant; in this case also we needn't worry about arcane geological details.

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[1](Bardi is a member of the ASPO (Association for the study of peak oil). He is the author of the book "La Fine del Petrolio" (the end of oil) and of several studies on oil depletion.

[2]Bardi, Ugo. "Abiotic Oil: Science or Politics?" *Abiotic Oil: Science or Politics?* From The Wilderness Publications, 2004.Web.<http://www.fromthewilderness.com/free/ww3/100404_abiotic_oil.shtml>.

Remember that this paper has been dedicated to helping the non-specialist in petroleum geology wade through the scientific details of the theory, and we have seen that the evidence for abiotic theory is compelling. Bardi chooses to focus on the potential consequences of what would happen were the abiotic theory true, and thus will attempt to argue that the abiotic theory cannot be true because these consequences have not occurred. As a side note, some readers will probably note that there is a third possibility that Bardi is not considering here. The abiotic theory could be true, and the consequences Bardi attaches to it could logically follow, but there could be a factor preventing them from occurring that is as yet undiscovered. The following example is an analogy where Bardi's logic is applied: Columbus thought that he could sail directly from the Europe to Asia. Logically, if the world was round, Columbus should be able to sail directly from Europe to Asia. Columbus was not actually able to sail directly from Europe to Asia, thus the earth is not round. The intervening factor here was, of course, the Americas, but since no one knew they existed, their existence could not be taken into account. Similarly, if a factor exists preventing Bardi's consequences from occurring even though they logically should occur, but we do not know of the factor, that does not mean the abiotic theory *must be* untrue, though admittedly it *could* mean that. Regardless, let's see what Bardi has to say about the consequences.

> Bardi distinguishes two versions of the abiotic theory:
>
> *The "weak" abiotic oil theory*: oil is abiotically formed, but at rates not higher than those that petroleum geologists assume for oil formation according to the conventional theory. (This version has little or no political consequences).
> *The "strong" abiotic theory*: oil is formed at a speed sufficient to replace the oil reservoirs as we deplete them, that is, at a rate something like 10,000 times faster than known in petroleum geology. (This one has strong political implications).

Bardi then continues by explaining his reasoning why the abiotic theory is flawed:

Both versions state that petroleum is formed from the reaction of carbonates with iron oxide and water in the region called "mantle," deep in the Earth.…Now, the main consequence of this mechanism is that it promises a large amount of hydrocarbons that seep out to the surface from the mantle. Eventually, these hydrocarbons would be metabolized by bacteria and transformed into CO2. This would have an effect on the temperature of the atmosphere, which is strongly affected by the amount of carbon dioxide (CO_2) in it. The concentration of carbon dioxide in the atmosphere is regulated by at least two biological cycles; the photosynthetic cycle and the silicate weathering cycle. Both these cycles have a built-in negative feedback which keeps (in the long run) the CO_2 within concentrations such that the right range of temperatures for living creatures is maintained (this is the Gaia model). The abiotic oil—if it existed in large amounts—would wreak havoc with these cycles. In the "weak" abiotic oil version, it may just be that the amount of carbon that seeps out from the mantle is small enough for the biological cycles to cope and still maintain control over the CO2 concentration. However, in the "strong" version, this is unthinkable. Over billions of years of seepage in the amounts considered, we would be swimming in oil, drowned in oil.

Thus Bardi argues that in the strong version of the theory, the earth would be swimming with oil, that we would be completely covered in it. Thus, it seems clear to Bardi that the strong theory is untrue. Perhaps the strong theory is indeed untrue, or perhaps there is a factor preventing this from occurring even though it logically should, such as a "full well" like regulating system – hydrocarbons only seep upwards if the oil wells are not full, once full, the hydrocarbons simply stay in the mantle and do not seep upwards. Either way, it is a legitimate concern about strong abiotic oil theory, even if it is not as large an anomaly as some of the anomalies found in fossil fuel theory. What then, does Bardi say about why weak abiotic oil theory is untrue? First, he writes that, "Indeed, it seems that the serious proponents of the abiotic theory all go for the 'weak' version." It is thus far more important to see why he argues weak abiotic theory is untrue than strong abiotic oil theory, if the majority of its proponents are in favor of weak abiotic theory. He writes:

> As a theory, the weak abiotic one still fails to explain a lot of phenomena, principally (and, I think, terminally): how is it that oil deposits are almost always associated to anoxic periods of high biological sedimentation rate? However, the theory is not completely unthinkable. At this point, we can arrive at a conclusion. What is the *relevance* of the abiotic theory in practice? The answer is "none." The "strong" version is false, so it is irrelevant by definition. The "weak" version, instead, would be irrelevant in practice, even if it were true. It would change a number of chapters of geology textbooks, but it would have no effect on the impending oil peak.

Bardi's response to weak abiotic oil theory is thus a rhetorical question and an evasion. He set out to prove abiotic theory false and instead asked his audience why it matters whether it is true or false. To be fair, Bardi, as we saw earlier, is a proponent of peak oil and the fossil fuel theory, and if the oil rate of abiotic oil generation is very similar to the rate of oil generation by biotic means, it really wouldn't make much difference for peak oil theories. However, remember that the purpose of Bardi's paper here is to prove that abiotic oil theory is untrue, not assert that it doesn't matter if it is true or not. Thus the strongest argument we have against the abiotic theory is ultimately no argument against it at all, merely a question why it matters.

Sadly, Bardi is not alone in his handling of abiotic oil theory, as many scientists do not critically engage abiotic oil theory on its merits and instead simply dismiss it. However, the abiotic experiment was only published in 2002, so perhaps there will be stronger arguments against it made soon, now that it cannot be so easily dismissed in a credible manner.

CHAPTER EIGHT

Conclusion

And so we come back once again to Thomas Kuhn and his paradigms. In Chapter Two we talked quite a bit about Thomas Kuhn and his views on the paradigm, normal science, the crisis, and the other facets of his theory of how science works. It seems that soon there may indeed become a crisis in oil theory. Is it abiotic or is it biotic after all? As we saw, recently some scientists have begun conducting extraordinary science in the forms of experiments looking to validate abiotic oil theory in the West. The anomalies are mounting for fossil fuel theory, but until 2002 normal science could just ignore the anomalies in its theory, there was no other credible paradigm waiting to replace the old one. It seems clear that now, however, we have two competing paradigms that have one of two things backing them – mounting evidence for abiotic theory, and years of tradition for fossil fuel theory. While tradition may seem a weak and illegitimate thing on which to base scientific theory, remember that Kuhn argued that not only is tradition something on which scientific belief can be based, but that tradition is something on which scientific belief is *very often* based. In the initial stages of pre-paradigmatic science, tradition is absent. In every other phase of scientific research, in post-paradigmatic science, tradition plays an ever increasing role in extending the paradigm's life. Initially, when there are few anomalies, tradition plays less of a role in upholding the paradigm – normal science holds it quite well. Later, as anomalies start piling up, as they clearly are for fossil fuel theory, tradition plays an ever increasing role. Thus we see that science is very unlike the ever-fair, quick to embrace new beliefs, and dogma free practice implied by the comments the new atheists made in Chapter Two – views on science that many laypeople hold. Dogma and tradition enslave science, and many scientists hold faithfully to the theories they were taught when they were young and have believed for years, even when new evidence arises dealing severe challenges to those beliefs.

Remember from Chapter Six all the anomalies facing fossil fuel theory? We saw evidence that not only is fossil fuel theory unlikely, it is literally impossible. We also saw that there have been scientists aware of this fact since the 19th century, yet still fossil fuel theory manages to survive. For over one hundred years fossil fuel theory has endured in the West even though some scientists have apparently proven it impossible. The scientific establishment and textbook theory is behind fossil fuel (remember, Withgott and Laposata, who we quoted earlier, are authors of a modern day environmental science textbook). Dismissals like Bardi's are apparently enough to discount abiotic theory. Perhaps that will no longer be the case in the future. Perhaps with the abiotic experiment conducted and published by Kenney et al. in 2002, there will be a real battle of the paradigms in the scientific community. Kenney et al. told us that there were many experiments that had been conducted previously that already proved their results, that oil is abiotic, but they had problems preventing them from being seen as quite as legitimate as Kenney et al.'s experiment. It is too soon to tell yet, however, because change comes slowly in the scientific community. It may happen tomorrow, it may happen decades from now, it may not even happen in our lifetimes. We will simply have to wait and see. One thing is certain, however. Kuhn's theory of how science is conducted is being proven every day by cases like the debate between fossil fuel theory and abiotic oil. Both theories are full blown paradigms because both determine the background on which petroleum geology will function. All further experiments in the field will be viewed through the lens of one theory or the other. Remember, facts are not viewed on their own in science – they are viewed through a paradigm. The potential change would be a major shift within the science of petroleum geology and the paradigm that shapes it.

CHAPTER NINE

Implications

We've covered the two different theories and how their clash supports Thomas Kuhn's idea of science. But beyond that, what does it mean for everyone else if oil is abiotic? What impacts could the abiotic oil theory have on politics? There is such a strong push for alternative energies in the United States and Europe, what if none of that is necessary? What if oil truly won't run out? We saw Ugo Bardi argue that oil can't be unlimited in any practical sense, because if it was, we'd be swimming in oil.[1]Thus he argued that abiotic oil would take a similar amount of time to generate as fossil fuel oil if the theory were true. What if oil wells stop filling once full, but start refilling once emptied? Could we simply drill forever? What if abiotic oil is generated quickly in the magma, but simply takes a very long time to reach drillable levels? What if it is created much, much faster than fossil fuel theory believes oil is created, but the similarity in timeframes Bardi sees is not a result of the rate oil is produced, but the rate at which oil seeps upwards in the crust? Could oil be unlimited if it were possible to drill to the magma and find it there? Perhaps. Beyond just the question of could we drill that far is the question of would it matter? Stanford S. Penner[2] offers the following concluding remark:

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[1]Bardi, Ugo. "Abiotic Oil: Science or Politics?" *Abiotic Oil: Science or Politics?* From The Wilderness Publications, 2004.Web.<http://www.fromthewilderness.com/free/ww3/100404_abiotic_oil.shtml>.

[2] (Distinguished Professor of Engineering Physics, Emeritus) Center for Energy Research Department of Mechanical and Aerospace Engineering University of California San Diego.

The final issue that must be addressed relates to the implications of the RU theory for future petroleum recoveries after drilling to depths of 100 km or more, which is well beyond currently existing capabilities. Progressively drilling deeper and deeper is a proper engineering challenge which may or may not be cost effective. Allowing natural processes to bring petroleum from lower depths to accessible levels will be as time consuming in the future as it has been in the past.[3]

[3]Penner, Stanford S. "Abiogenic or Biogenic Petroleum."Center for Energy Research Department of Mechanical and Aerospace Engineering University of California San Diego, n.d. Web.

Appendix

[I]**Because the H–C system typical of petroleum is generated at high pressures and exists only as a metastable mélange at laboratory pressures, special high-pressure apparatus has been designed that permits investigations at pressures to 50 kbar and temperatures to 1,500°C, and which also allows rapid cooling while maintaining high pressures** (28). The importance of this latter ability cannot be overstated; for to examine the spontaneous reaction products, the system must be quenched rapidly to ‘‘freeze in’’ their high-pressure, high-temperature distribution. Such a mechanism is analogous to that which occurs during eruptive transport processes responsible for kimberlite ejecta and for the stability and occurrence of diamonds in the crust of the Earth. **Experiments to demonstrate the high-pressure genesis of petroleum hydrocarbons have been carried out using only 99.9% pure solid iron oxide, FeO, and marble, $CaCO_3$, wet with triple-distilled water. There were no biotic compounds or hydrocarbons admitted to the reaction chamber.** The use of marble instead of elemental carbon was intentionally conservative. The initial carbon compound, $CaCO_3$, is more oxidized and of lower chemical potential, all of which rendered the system more resistant to the reduction of carbon to form heavy alkanes than it would be under conditions of the mantle of the Earth. Although there has been observed igneous $CaCO_3$ (carbonatite) of mantle origin, carbon should be more reasonably expected to exist in the mantle of the Earth as an element in its dense phases: cubic (diamond), hexagonal (lonsdaleite), or random-close pack (chaoite). **Pressure in the reaction cell**, as described in ref. 25, **of volume 0.6 cm^3 was measured by a pressure gauge calibrated using data of the phase transitions of Bi, Tl, and PbTe. The cell was heated by a cylindrical graphite heater; its temperature was measured using a chromel-alumel thermocouple and was regulated within the range ±5°C. Both stainless steel and platinum reaction cells were used; all were constructed to prevent contamination by air and provide impermeability during and after each experimental run.**

[II]**The pressure of 30 kbar, at which the theoretical analyses** of section 4 **predicts that the H–C system must evolve ethane and heavier hydrocarbon compounds, corresponds to a depth of more than 100 km. The results of the theoretical analysis shown in Fig. 2 clearly establish that the evolution of the molecular components of natural petroleum occur at depth *at least* as great as those of the mantle of the Earth, as shown graphically in Fig. 4, in which are represented the thermal and pressure lapse rates in the depths of the Earth. As noted, the theoretical analyses reported in section 4 describe the high-pressure evolution of hydrocarbons under the *most favorable* chemical conditions.** The theoretical calculations for the evolution of hydrocarbons posited the presence of methane, the genesis of which must itself be demonstrated in the depths of the Earth consistent with the pressures required for the evolution of heavier hydrocarbons. **Furthermore, the multicomponent system analyzed theoretically included no oxidizing reagents that would compete with hydrogen for both the carbon and any free hydrogen. The theoretical analysis assumed also the possibility of at least a metastable presence of hydrogen. Therefore, the theoretical results must be considered as the determination of *minimum* boundary conditions for the genesis of hydrocarbons. In short, the genesis of natural petroleum must occur at depths not less than ≈100 km, well into the mantle of the Earth. The experimental observations reported** in section 5 **confirm theoretical predictions** of section 4, **and demonstrate how, under high pressures, hydrogen combines with available carbon to produce heavy hydrocarbon compounds in the geochemical environment of the depths of the Earth.**

[III]Notwithstanding the generality and first-principles rigor with which the present theoretical analysis has used, the results of the theoretical analyses here reported are robustly independent of the details of any reasonable mathematical model. **The results of this theoretical analysis are strongly consistent with those developed previously by Chekaliuk and Kenney** (29–32) **using less accurate formal tools. The analysis of the H–C system at high pressures and temperatures has been impeded previously by the absence of reliable equations of state that could describe a chemically reactive, multicomponent system at densities higher than such of its normal liquid state in ordinary laboratory**

conditions and at high temperatures. The first analyses used the (plainly inadequate) Tait equation (33); **later was used the quantum mechanical Law of Corresponding States** (34); **more recently has been applied the single-fluid model of the SPHCT** (31, 32). **Nonetheless, all analyses of the chemical stability of the H–C system have shown results that are qualitatively identical and quantitatively very similar: all show that hydrocarbons heavier than methane cannot evolve spontaneously at pressures below 20–30 kbar. The H–C system does not spontaneously evolve heavy hydrocarbons at pressures less than ≈30 kbar, even in the most favorable thermodynamic environment. The H–C system evolves hydrocarbons under pressures found in the mantle of the Earth and at temperatures consistent with that environment.**

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