Petrified Ideas of the Williston Basin

Part III: Coal and Oil

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Abstract

The Williston Basin of central North America contains prodigious quantities of coal and oil. Could the antediluvian biosphere have provided this carbon mass, or did it require many millions of years to accumulate? In this concluding part, we focus on fossil fuels. As we have seen many times in many places, what appear to be strong arguments against the Biblical view of Earth history turn out to be strong arguments against uniformitarianism.

Key Words: petrogenesis, coal, oil, Williston Basin, Bakken Formation, lignite, pyrolysis

Introduction

The geologic setting of the Williston Basin was provided in Part I of this series, while Part II focused on fossil wood. While the nearly 5,000 m (over 16,000 ft.) of sediments filling the Williston Basin (Figure 1) are said to represent all the geologic systems in the standard story of Earth history, providing an impressive argument against the Biblical account closer examination in the light of recent scientific advances puts the shoe on the other foot. The idea of gradual deposition in a gradually subsiding basin in concert with eustatic depth changes in the basin now appears to be a petrified idea with many scientific difficulties.

Likewise, the Fort Union Group strata that form the bulk of the badlands in North Dakota exhibit evidence of rapid, continuous deposition. Instead of huge swamps with gradual soil formation leading to coal formation and fossilization of trees, catastrophic conditions of at least regional extent would have been necessary to preserve the wood and other organic matter, and coalify or fossilize it. The mineralogy and sedimentology of the Fort Union Group supports this view rather than the traditional story. This paper addresses fossil fuels in the Williston Basin. The focus is the deeper part of the basin as shown in Figure 2.

Importance

While the Williston Basin has produced lignite-rank coal and crude oil for many years, it was the advent of two technologies that revolutionized production in the basin. Directional drilling with horizontal completion and hydrofracturing ("fracking") tapped the enormous potential of the Bakken Formation and triggered the Bakken oil rush, which the lead author experienced, working in Watford City, North Dakota, the heart of the Williston Basin. Nearing the North Dakota border at night, one could see a thousand giant gas flares from new oil wells across the prairie. There was memorable hoopla when North Dakota oil production exceeded one million barrels per day (Table I).

Estimates of total reserves of the basin, by the USGS and others, range from a century to a millennium at today's production rates. The amount in the Bakken Formation alone is mind bog-

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Accepted for publication November 16, 2021

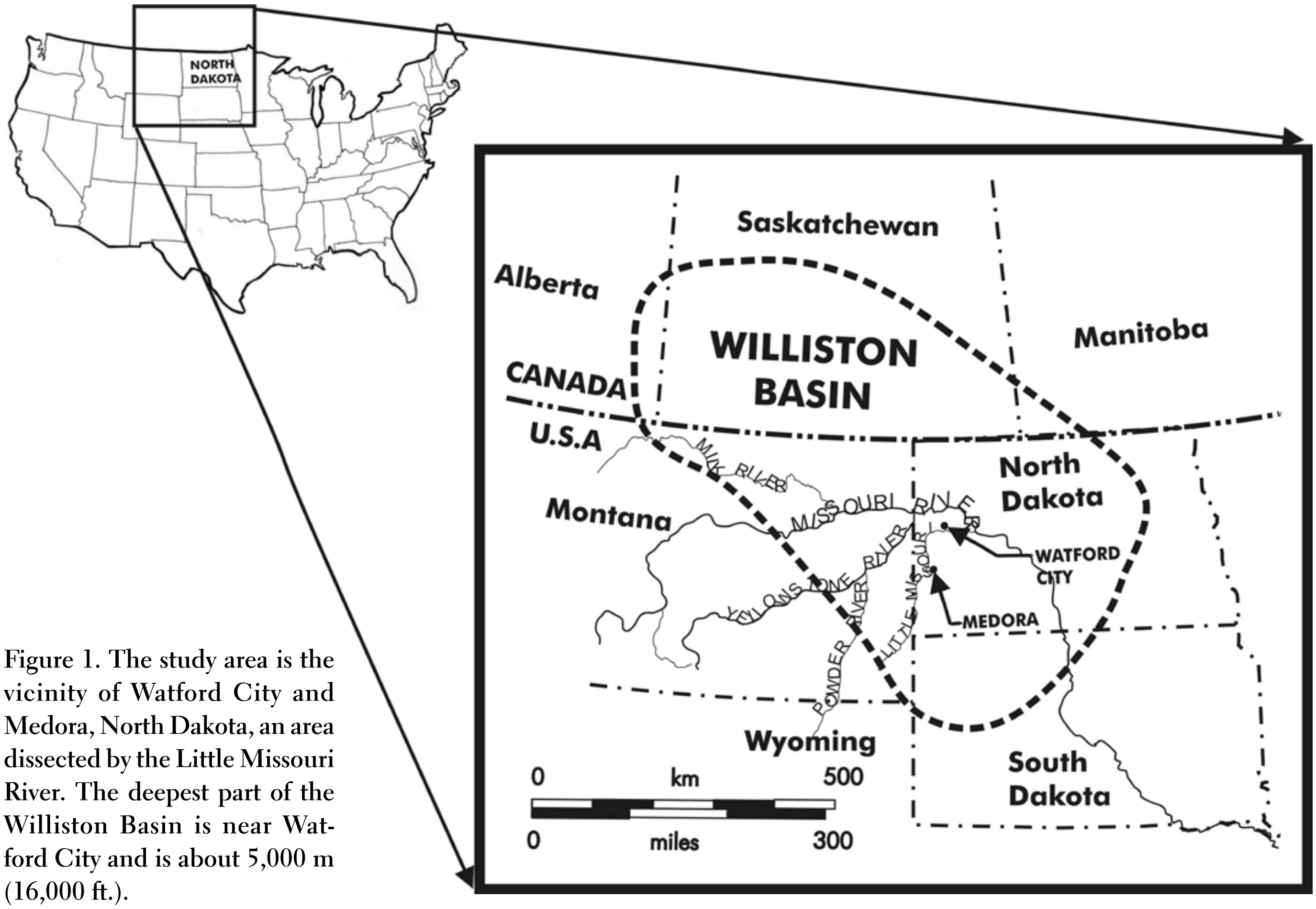

Figure 1. The study area is the vicinity of Watford City and Medora, North Dakota, an area dissected by the Little Missouri River. The deepest part of the Williston Basin is near Watford City and is about 5,000 m (16,000 ft.).

gling. Crude oil and sub-par kerogenous matter are found in lesser quantities in the Three Forks and other formations (Figure 3). The strata nearer the surface are characterized by abundant lignite.

The Williston Basin: Endless Supplies of Fuel?

Enormous amounts of organic matter, largely terrestrial vegetation and marine algae, were buried in the basin. In deeper formations, it forms crude oil and natural gas. In the shallower strata of the Fort Union Group, most of it is preserved as low-rank coal (lignite or "brown coal").

Conventional Plays

Oil has been extracted from several fields in the basin for many years. "Conventional plays" are those where oil has migrated from carbon-rich source rocks to reservoirs, usually sandstones, and is extracted by vertical wells. These plays tend to be found in structural traps such as the Nesson Anticline, Poplar Dome, and Cedar Creek Anticline (Figure 2).

The Bakken Formation

Type localities are usually outcrops representative of the formation. However, the type locality of the Bakken Formation is from subsurface drill cores (subcrop). The Bakken is easily located geophysically and is buried deep in the basin (Figure 3, number 11). It consists of four members (LeFever et al., 2012; Stroud, 2012; Sonnenberg, 2017), not all of which are present at all places: the basal *Pronghorn Member* ("Sanish sand"), consisting of sandstones, siltstones, and carbonaceous mudstones of limited areal extent; the *lower shale member*, an organic-rich black shale source rock; the *middle member*, consisting of silty dolostone, limestone, and sandstone; and the *upper shale member*, similar to the lower shale. The shales are interpreted by sequence stratigraphers as hemipelagic muds from transgressive systems tracts (see Part I), with the Bakken at the base of the Kaskaskia Megasequence. This interpretation has, however, been disputed (e.g., Petty, 2019). Evidence of bioturbation appears at odds with an anoxic (euxinic to dysoxic) environment, which supposedly explains the 3% to 10% total organic carbon content (Egenhoff and Fishman, 2013). Multiple sediment sources or directions are postulated (Mohamed, 2015).

Petroleum Systems

Six petroleum systems (source rocks generating oil and gas, collected in reservoir rocks, and capped by seals) are recognized in the Williston Basin (Nordeng, 2013). These are shown in Figure 3. Oil in the Three Forks Formation is part of the Bakken system, as it is believed to derive from Bakken source rocks. The Bakken is the primary producer today. Petroleum systems are identified by physical properties, geochemistry, and biomarkers of the oils (Jarvie, 2001; Lillis, 2013; Auers et al., 2014; Yang et al., 2017).

The Fort Union Group

The Fort Union Group (Fort Union Formation in Montana) contains several similar formations (or members) of weak, clastic sedimentary rocks (Klevberg and Oard, 2021). These strata are laterally extensive but not continuous across the Williston Basin. Marker beds, usually major coal seams, are not abundant. Bentonite is common, derived from volcanics but with fragments of metamorphic rocks transported from mountains more than one hundred miles to the west or southwest. Where coal has burned, it forms clinker beds. These rocks weather

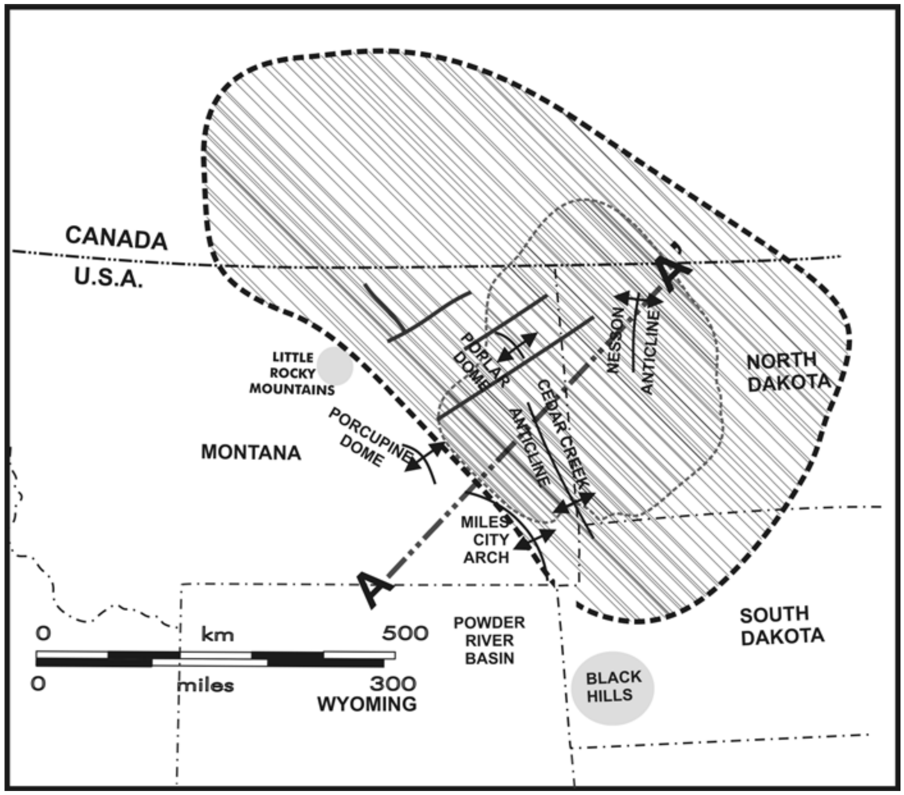

Figure 2. Relation of Williston Basin to nearby structures. Antiforms are found within the basin as well as to the west. Area of darker hatching is central (deeper) part of basin. Cross section indicated by line A–A' is shown in Figure 3.

Table I

Bakken Development History			
Year	**Field**	**Event**	**Location (Figure #)**
1953	Antelope	Earliest discovery	Southeast spur of Nesson Anticline
1961	Elkhorn Ranch	Shell well completed in upper shale	Halfway between Watford City and Medora
1976	Bakken Fairway	Next well in Bakken, first in Fairway	Between Nesson and Cedar Creek Anticlines
1987	Fairway	First horizontal well, in upper shale	
2006	Parshall	Discovery of Parshall Field, beginning of boom	East of Nesson Anticline
2007	Elm Coulee	Development of middle Bakken	Southeast of Poplar Dome
2012	entire Williston Basin	peak of 217 active drilling rigs	Closely hatched (inner area) inside gray dashed line
2014		production first exceeded one million barrels a day	

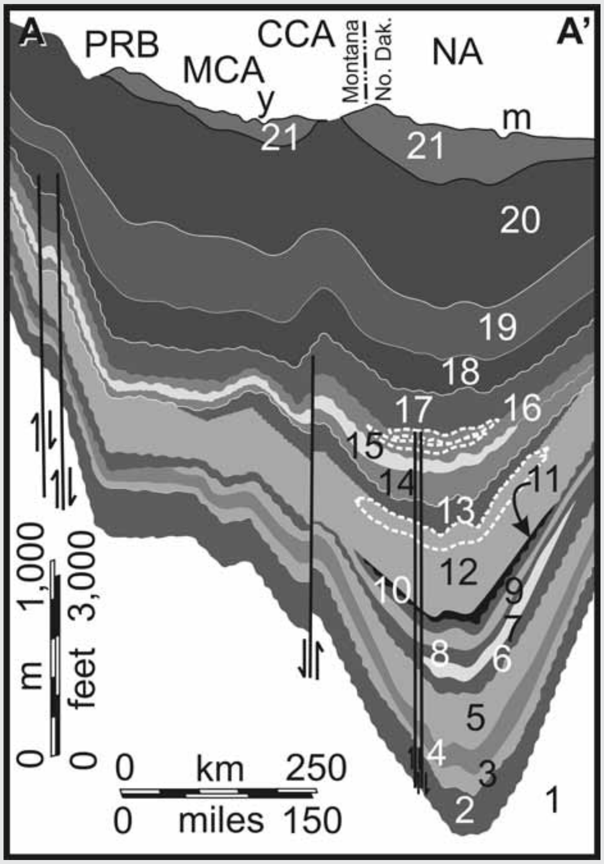

Figure 3. Southwest–northeast cross section through Williston Basin along line indicated on Figure 2. Figure modified from Peterson (1988). Charles Formation and Spearfish Formation Fine Salt and Dunham Salt Members indicated by dashed white lines.

PRB Powder River Basin
MCA Miles City Arch
CCA Cedar Creek Anticline
NA Nesson Anticline
y Yellowstone River
m Missouri River
italics indicates petroleum system source rocks

1 Metamorphic basement
2 Deadwood Formation
3 Winnipeg Group (Black Island, Ice Box, and Roughlock Formations)
4 *Red River*, Stony Mountain, and Stonewall Formations, undivided
5 Interlake Formation
6 *Winnipegosis* Formation
7 Prairie Formation (Prairie Salt)
8 Manitoba Group (Dawson Bay and Souris River Formations)
9 Jefferson Formation (*Duperow* and Birdbear Members)
10 Three Forks Formation
11 *Bakken* Formation
12 *Madison* Group (Lodgepole, Mission Canyon, and Charles Formations; Charles indicated by dashed line)
13 Big Snowy Group (Kibbey, Otter, and Heath Formations)
14 Amsden Group (*Tyler*, Alaska Bench, and Devil's Pocket Formations; eastward may be referred to as Tyler, Amsden, and Minnelusa Formations)
15 Opeche and Minnekahta Formations, undivided
16 Spearfish Formation (Fine Salt and Dunham Salt Members indicated by dashed lines)
17 Ellis Group (Piper, Rierdon, and Swift Formations; strata assigned to Morrison Formation included)
18 Dakota Group (Inyan Kara, Skull Creek, Newcastle, and Mowry Formations; some refer to Inyan Kara Group with Lakota, Fusion, Fall River—Dakota; Skull Creek and above assigned to Colorado Group)
19 Colorado Group (Graneros—Mowry, Belle Fourche, Greenhorn, Carlisle, and Niobrara Formations; Skull Creek and Newcastle included by some at base)
20 Montana Group (Telegraph Creek, Eagle, Claggett, Judith River—Pierre—Bearpaw, Fox Hills, and Hell Creek Formations)
21 Fort Union Group (Ludlow, Slope, Cannonball, Bullion Creek, and Sentinel Butte Formations; in Montana, Fort Union Formation with Tullock, Ekalaka, Lebo, and Tongue River Members)

to badlands topography which cuts deeply into the group (Figure 4). The Fort Union strata are the lowest exposed rocks in the area; deeper formations are all subsurface.

Fort Union Lignite

The Fort Union Group contains immense amounts of lignite (Figure 5).

> The lignite area covers more than 28,000 square miles (18 million acres). More than 100 beds over four feet in thickness have been identified…. Strippable reserves are estimated to total 16.1 billion tons…. (Dalsted and Leistritz, 1974, p. 4).

More than a century ago, the enormous extent of this resource was already recognized and being tapped (Herald,

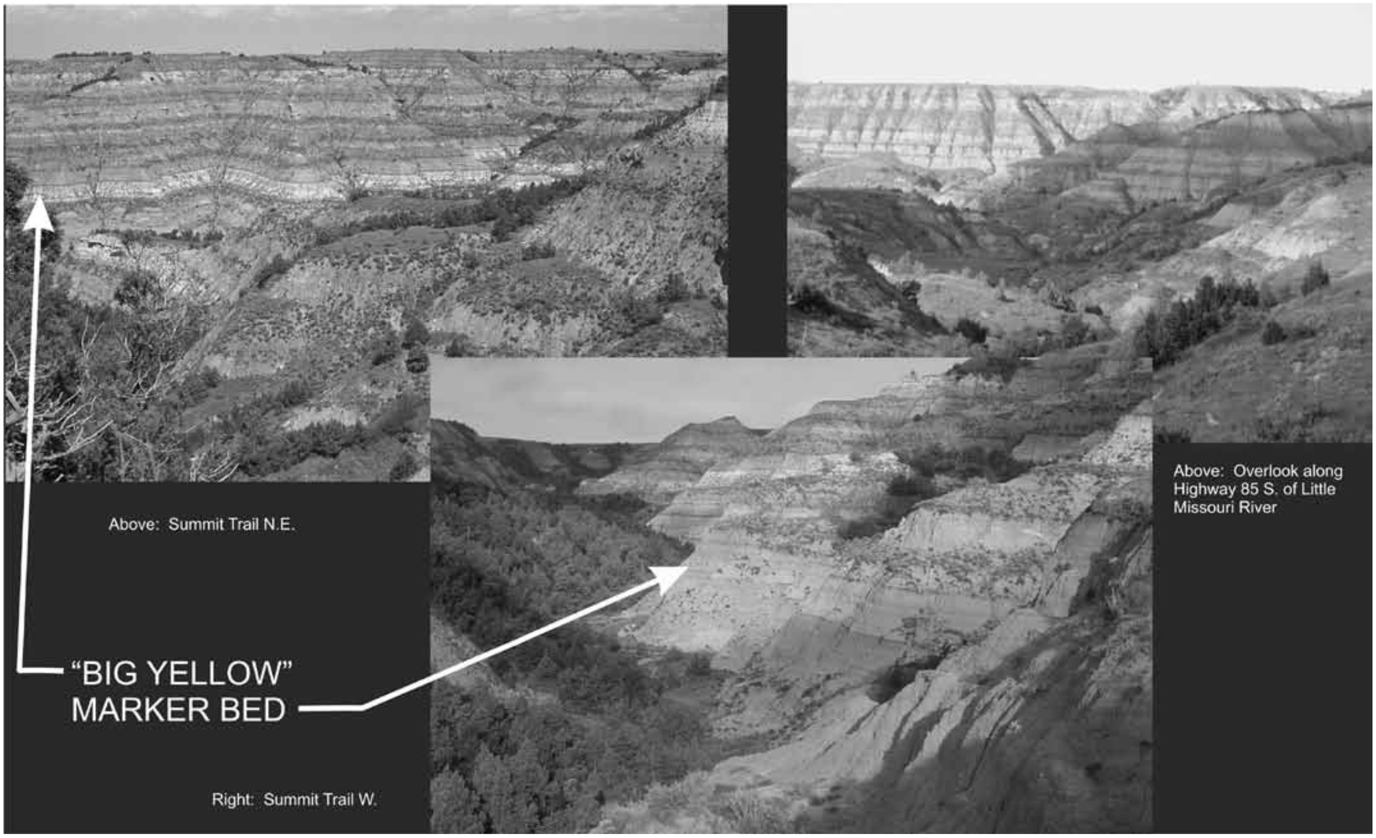

Figure 4. The uppermost formation in the Fort Union Group is the Sentinel Butte Formation, and the deeply dissected badlands provide abundant exposures. These three views from the badlands of McKenzie County show the lateral continuity of strata. Marker beds such as the "big yellow," "big blue," HT lignite, L lignite, and "upper yellow" are important stratigraphic markers, but none extends the width of the basin. The coal therefore did not form from a mass of vegetation of basinal extent but instead from large but isolated mats or masses.

1911). Many of the seams are thin (Figure 6), but thick, extensive ones serve as marker beds.

The lignite of the Williston Basin (Figure 5) seems like the continuation of the extensive coal in the Powder River Basin, deposited by a north-to-northeast diluvial current. Several of the 47 Tertiary coal seams greater that 1.5 m (5 ft.) thick in the Powder River Basin exceed 30 m (100 ft.) in thickness (Jones, 2010; Luppens et al., 2015). The Powder River coal is low sulfur, subbituminous A to subbituminous C. The differences in coals can be explained by the subsequent overburden and erosion. Assuming a geothermal gradient of 26–27°C/km (24–26°F/1,000 ft.), lignite requires an overburden of 100–1,600 m (330–5,250 ft.), while the Powder River Basin coal would require 1,600–3,200 m (5,250–10,500 ft.) (Thomas, 2013, p. 111).

The Pyrolysis Problem

Thermal maturity is the degree to which kerogen converts to petroleum or coal by pyrolysis. The concept is simple: heat at depth breaks carbon-carbon bonds in large molecules. Reduction in oxygen, sulfur, nitrogen, and hydrogen, and hydrogenation of the resulting fragments, forms smaller ones. Branched alkanes and aromatics are also formed. Though straightforward, several problems arise. Difficulties forming petroleum from organic matter have caused some to look for an abiologic source. Thermodynamic stability relations (free energies and activation energies) argue against common explanations. The enthalpy of the system must decrease. If vast time is required, it may not be possible for the molecules to persist. Carefully managed processes in oil refineries that use exotic catalysts may make poor analogues for natural processes.

Organic versus Inorganic Origin

Petroleum is largely believed to be biogenic. Kenney et al. (2002) argued

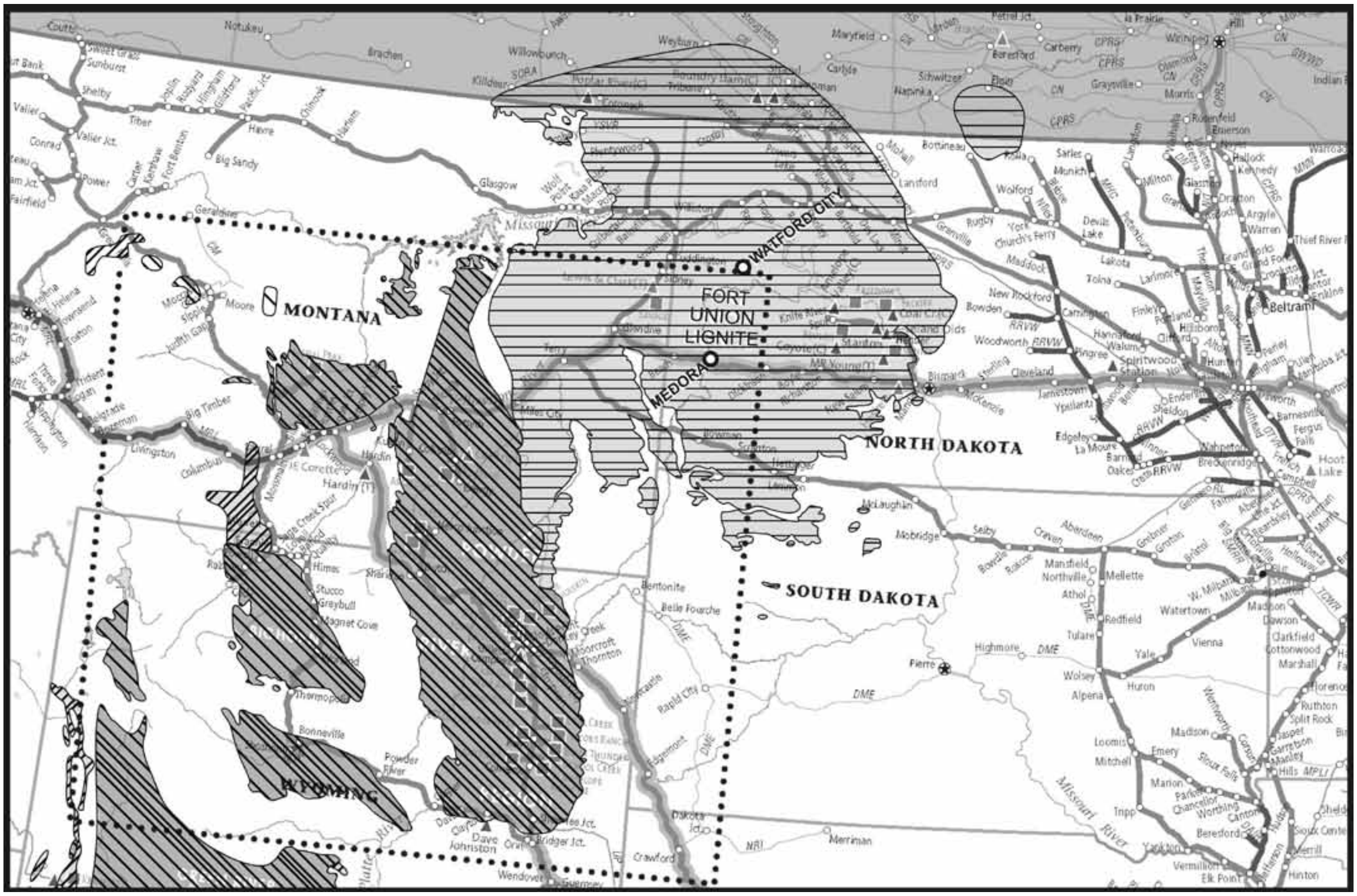

Figure 5. Map derived from BNSF Railway 2013 Coal Map with coal mines and railroad system shown. Sub-bituminous and bituminous coal indicated by diagonal hatching and lignite by horizontal hatching. Dotted square is primary Powder River Basin coal mining and rail haulage area.

on chemical thermodynamic grounds for an abiologic origin in the mantle, a view largely promoted by Russian researchers but not accepted in the West. Experimental evidence for the possibility of thermodynamically favorable generation of methane and larger hydrocarbons from carbonate minerals at high pressures has been presented (Scott et al., 2004). Vestiges of chlorophyll, sulfur bacteria, and other levorotary (left-handed chirality) biogenic molecules appear to argue in favor of a biologic origin (Jiang et al., 2001; Yang et al., 2017) as does a preponderance of odd-numbered alkanes in various crude oils. Matthews (2008, p. 154) disputes this and proffers a "theobaric" origin for most oil: "A very specific burial history must occur for the kerogen to be heated to the correct temperatures for the correct amount of time to form oil." This burial history is the object of basin modeling.

Basin History

Burial history is commonly modeled by PETROMOD or BASINMOD software (Figure 7). Model output can be quite impressive, but the reasoning is circular, and results can diverge from field conditions (Matthews, 2008). The time required for petrogenesis as commonly modeled has also been refuted by observation of recently formed oil in the Gulf of California, the result of hydrothermal activity on the sea floor and not the multistep process commonly modeled.

> Such a slow, multistep mechanism differs significantly from hydrothermal petroleum formation, which can be geologically fast… in which generation occurs almost concurrently with expulsion and migration (Didyk and Simoneit, 1989, p. 69).

Stability and Time

"The generation of hydrocarbons, even at these temperatures [100–120°C], is very slow and requires time on the scale of millions of years to produce significant volumes of hydrocarbons" (Nordeng, 2013, p. 11). Higher temperatures cause oil to break down into condensate and natural gas, but lower temperatures greatly slow the pyrolytic reactions. However, petroleum hydrocarbons experimentally generated from carbonate minerals were quenched to prevent transformations that may have occurred if the apparatus had been cooled slowly (Kenney et al., 2002). Anaerobic conditions, even deep in the Earth, do not preclude microbial degradation of hydrocarbons (Gray et al., 2010). We rely on anaerobic degradation to clean up petroleum pollution on a year-to-decade scale, so even if deep microbial activity is three orders of magnitude slower than near the surface, millions of years should result in complete conversion to methane and heavy oil or inert kerogen. Thus, conflicting ideas include source *and* time.

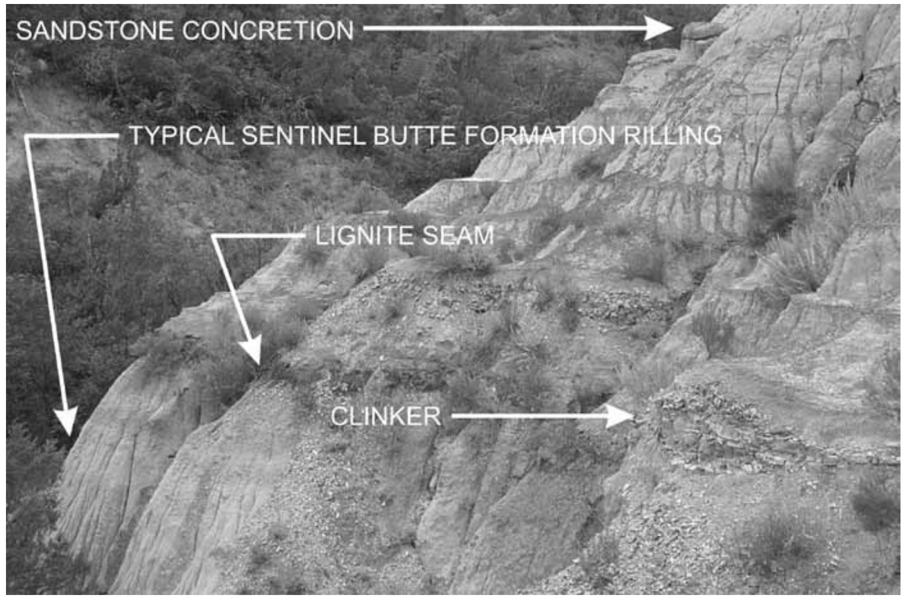

Figure 6. Typical exposure of Sentinel Butte Formation in McKenzie County, North Dakota. Concretions in sandstone are common. The rilling shown here is typical of the Sentinel Butte strata, as is the thinness of the lignite seam. Lignites and clinker are often associated, sometimes transitioning laterally where oxygen deprivation probably prevented further burning of the coal.

Problems for Diluvialists

Diluvialists are significantly restricted by time. While the formation and filling of the Williston Basin is difficult for evolutionists (Klevberg and Oard, 2021), petrogenesis presents challenges for creationists. Can oil form that rapidly? Was it abiogenic, biogenic, or both? Or is it a mystery transcending natural explanation (Matthews, 2008). Creationists have only provided preliminary answers (Ouweneel, 1977; McQueen, 1986; Snelling, 1990), but recent experiments provide illumination.

Experimental evidence indicates oil can form rapidly. Torbanite is oil shale, boghead coal, or cannel coal (Figure 8) that is believed to be derived primarily from algal kerogen and can yield paraffinic or asphaltic oil when heated. Experiments on torbanite and brown coal over a period of six years provided some very important results (Saxby et al., 1986, p. 80):

> Overall, the two most significant results are (i) the absence of olefins and carbon monoxide in all major products, as in naturally-occurring hydrocarbons and (ii) remarkable experimental verification of the vitrinite coalification line from brown coal to anthracite…the results show that natural maturation reactions can be simulated both in the presence and absence of water.
>
> The present experiments clearly show that altering the time-scale of source rock pyrolysis from seconds to years (i.e. a factor of 10^7) changes the product distribution to that of natural petroleum. In many geological situations much longer time intervals are available but evidently the molecular mechanism of the decomposition is little changed by the additional time. Thus, within sedimentary basins, heating times of several years are sufficient for the generation of oil and gas from suitable precursors.

As shown on Figure 8, boghead or cannel coal mature through the oil window on the path to anthracite coal. Synthetic crude oil from algae (Helman, 2013) and slaughterhouse waste (Lemley, 2006) has been produced at both bench and plant scales in less than one hour. The Carthage, Missouri, plant (Lemley, 2006) subjected the slaughterhouse waste to 20 minutes at 260°C (500°F) and 4.1 MPa (600 psi) to produce 500 barrels per day of high-quality light crude oil. Laboratory results indicate that many oil properties can be produced at high temperatures for short times versus low temperatures for long times (Liang et al., 2015). Some differences in relative abundances of alkanes and other compounds varied with temperature. "The temperature range of maximum hydrocarbon generation for Type I kerogen corresponds to 350–450°C" (Liang et al., 2015, p. 212). For planktonic (Type II) kerogen,

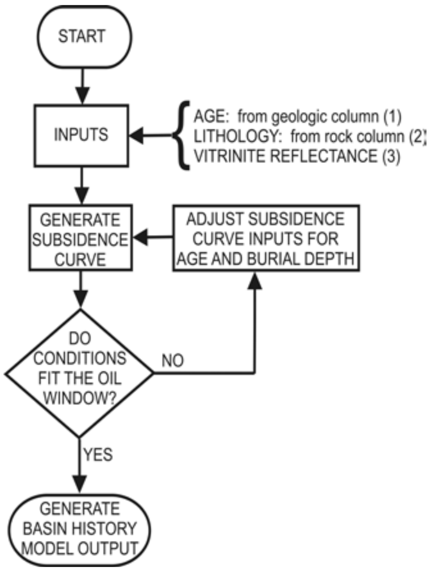

Figure 7. PETROMOD and BASINMOD rely on several inputs: (1) age is *assumed* starting with the geologic column, (2) lithology is scientifically derived from the rock column, which is usually a combination of drilling and geophysical data, but the sediment is *assumed* to have begun cold and warmed as it was slowly buried *assuming* the current geothermal gradient, (3) vitrinite reflectance, a measured value, is *assumed* to accurately indicate thermal *maturity*, though this may not be the case (Wenger and Baker, 1987). The program goes through iterations to compute burial depth and rate based on assumed initial conditions and pyrolysis. Pyrolysis is *assumed* to have taken place over vast ages, i.e., equilibrium conditions, which places a relatively low maximum temperature on the system; otherwise, molecules would have been reduced to natural gas (see Figure 8).

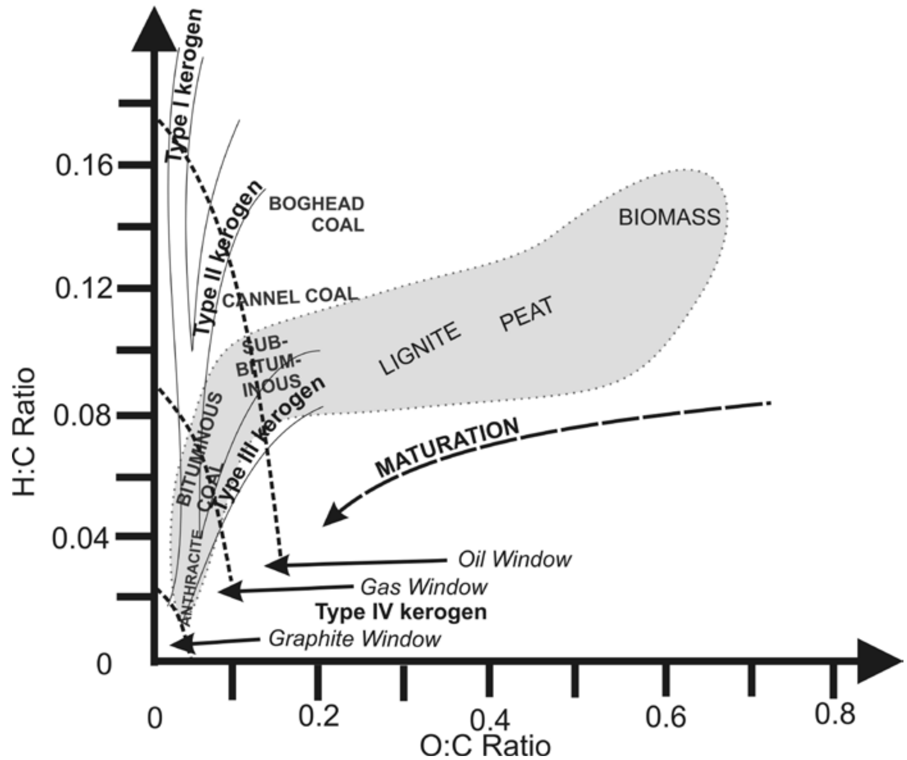

Figure 8. Van Krevelen diagram derived from Harwood (1977) and a multitude of other sources. The oxygen:carbon is the abcissa, and the hydrogen:carbon is the ordinate. Maturation (heavy dashed line) results in lowering of both ratios as hydrogen and oxygen are released. Kerogen types (Table II) show different ratios and plot in different parts of the diagram. Primary path of coal maturation follows the shaded area. Maturation of petroleum follows the general maturation trajectory with the "oil window" and "gas window" demarcated by the curves with short-dashed lines. Thus, oil will form inside the "oil window" and turn to gas after passing into the "gas window" with further maturation (pyrolysis). A residue of pure carbon from which all O and H have been stripped by pyrolysis would be graphite.

maximum productivity was between 300 and 450°C.

Matthews (2008) noted the objection to migration of hydrocarbons per Darcy's Law on a scale of thousands of years. However, many assumptions are involved in that calculation, including: viscosity and interaction with water, porosity changes, and migration pathways. Viscosity is temperature related, and the assumption that organic matter began cool and heated gradually with burial is shaky. In a diluvial model, we would expect elevated temperatures during the Genesis Flood.

Coal maturation is similar to that of petroleum (Figure 8). While Type II kerogen may have mixed terrigenous and marine organic materials, Type III is dominated by woody plants and more likely to produce coal and natural gas (Table II). Oard and Klevberg (2022) noted the role of floating mats of logs and woody debris in coal formation in the Fort Union strata. Other creationists have provided evidence for rapid transport, deposition, and burial of plant matter to form fossilized wood or coal (see Appendix).

The Carbon Quantity Conundrum

The amount of organic material in petroleum and coal has been estimated as being many times that of the

Table II

Types of Kerogen				
Type	**Description**	**Source**	**Prominent Maceral**	**Products**
I	sapropelic	bacteria, algae, proteins, waxes, fatty acids	alginite	oil
II	planktonic	plankton, bacteria, marine organic matter	exinite	oil and gas
III	humic	cellulose, woody plants	vitrinite	gas, coal
IV	inert	charcoal, peat, polyaromatic hydrocarbons	inertinite	coal, graphite

present biosphere, a point addressed by Froede (1995), Wiant (1974), and Woodmorappe (1999). Archer (2010) estimated that there is eight times as much carbon in coal as in the current terrestrial biosphere. Uniformitarians have millions of years for organic matter to accumulate in anoxic basins; creationists must find another answer. In the case of coal, the organic matter was largely terrestrial plants. As shown in Table III, greatly accelerated rates of production of Types I and II kerogen would be expected during the Deluge, but this would not explain the apparent lack of *volume* of terrestrial plants. Type IV kerogen also would have had terrestrial plant precursors (Achten and Hofmann, 2009). This is a large amount of vegetation, but there are possible explanations: the land/sea ratio was larger, there were few if any deserts or semi-arid areas, and/or the climate was warmer and wetter (Oard and Reed, 2017). Given these, the carbon reservoir of the antediluvian world could have been sufficient.

Problems for Uniformitarians

Hydrocarbon formation is problematic for uniformitarians too. In addition to the pyrolysis problem, gradual accumulation in anoxic basins might be exceeded by anaerobic microbial degradation. Furthermore, bioturbation is evident in the "oxygen-deprived" environment of the Bakken! The idea of slow pyrolysis of kerogen followed by slow migration to reservoirs per Darcy's Law has been called into question by recent field and laboratory studies. Oil has been created from slaughterhouse waste, algae, and plastic garbage in less than one hour, at reasonable temperatures and pressures. Basin modeling software assumes deep time; the fallacy of begging the question (*petitio principii*). Preservation of organic matter and generation of kerogen and bitumen is best accomplished through rapid burial in a hot environment.

Another problem is the existence of over-pressured reservoirs in the Williston Basin (Sonnenberg, 2017), North Sea (Matthews, 2008), and elsewhere (Armstrong, 1972). No geologic seal is perfect, and after many millions of years, pressures should be greatly reduced regardless of how slight the leakage.

Oil is also found in the "wrong" places. In some cases, downward migration from source rocks appears plausible. Sun et al. (2019) invoke bacteria as the source for Hongshuizhuang Formation shale source rocks (Gaoyuzhuang Formation carbonate reservoir) but explain anomalous biomarkers by contamination. In deep petroleum systems, evolutionists *must* invoke contamination since they believe few living things existed when the rocks were deposited.

The origin of coal has been extensively debated, though the prehistoric swamp theory adorns signs and booklets at tourist traps like Medora, North Dakota (Figure 1). The architecture of the Fort Union Group (Figure 4) is too laterally extensive to fit the uniformitarian model of migrating delta swamps transgressing the isochronous horizon. As has been pointed out many times (see Appendix), the texture or fabric of many coals refutes a peat origin. Evidence for an allochthonous (floating mat) origin has mounted in recent decades. It gained traction with Austin's (1979) study of Appalachian coal and those of Mt. Saint Helens catastrophism (Morris and Austin, 2003; Coffin et al., 2005; Oard and Reed, 2017). Kerogen III (Table II), while primarily terrigenous, often contains marine materials, and marine fossils occur in some coals (Coffin et al., 2005). Alleged paleosols underlying coals have been widely disproven (Froede, 1998), as have those in conjunction with petrified wood (Oard and Klevberg, 2022). The extent, thickness, and textures of

Table III

Carbon Sources		
Source	**Kerogen**	**Diluvial Conditions**
bacteria	I	Probably large blooms when nutrients and temperatures elevated.
algae	I	Probably large blooms when nutrients and temperatures elevated.
plankton	II	Probably large blooms when nutrients and temperatures elevated.
plants	III and IV	Probably assembled into mats by marine currents and deposited in large masses.
mantle (abiogenic)		Abiogenic carbon and hydrocarbons could have been released from fountains of the deep.
carbonates		Hydrocarbons could have formed from deep carbonates, possibly erupted with carbonatites.

coal do not fit with the swamp explanation. While belief in an *old earth* would not preclude acceptance of catastrophism or rapid, continuous deposition of the Fort Union strata, commitment to *uniformitarianism* would. Uniformitarians also have difficulty explaining the purity of the Powder River Basin coal. Why are there not more fluvial sediments and volcanic ash within the coal seams?

Inferences and Conclusions

The Williston Basin is a key source of fossil fuels: gas, oil, and coal. Organic matter occurs in high concentrations in several formations there. Six petroleum systems are generally recognized, the most important being the unconventional Bakken play. Lignite is found in great quantity in the Fort Union Group near the surface.

The pyrolysis problem is one of temperature versus time. By assuming vast time, researchers are limited to relatively low temperatures or hydrocarbons will "overmature" to dry gas. Darcy's Law often suggests long periods of time for hydrocarbon migration to reservoir rocks. Basin models are based on this multistep, slow process and assume deep time. These models mix inputs from science and history; only the former is subject to direct testing. Model results often fail to correspond to field conditions, suggesting a problem with the historical component of the model. Pyrolysis can occur in as little as 20 minutes at the right temperatures and pressures. It appears in nature at advanced rates with hydrothermal activity. Hydrothermal petrogenesis results in maturation simultaneous with migration in agreement with the diluvial geologic paradigm. Initial conditions during the Deluge would likely have included warmer temperatures favoring pyrolysis and faster migration of pyrolytic products. Experimental evidence also shows that light hydrocarbons can be generated directly from carbonate minerals at mantle temperatures and pressures without kerogen. Petroleum may therefore be produced from both biologic and abiologic sources in short periods of time. Over-pressured reservoirs also expose this time discrepancy. Petrified thinking—adherence to belief in deep time and uniformitarianism—appears to be the primary reason for the slowness to adopt these new findings in modeling and exploration.

The carbon problem is one of mass. Uniformitarians appeal to anoxic basins for preservation of slowly accumulating organic matter, an exercise in extended equilibrium inconsistent with the Bakken Formation. The vast amounts of carbon found in the rock record can be partly explained by optimal conditions during the Deluge for production of types I and II kerogen, but this does not apply to types III and IV. These types of kerogens can be explained by a lush antediluvial terrestrial biosphere, potentially greater land area, and the BEDS model (Oard, 2014; Oard and Reed, 2017).

Coal has traditionally been interpreted as forming in in swamps, but evidence favors allochthonous formation, probably largely from mats of vegetation swept onto depositional surfaces by marine or diluvial currents (Oard, 2014). The same arguments presented in Part II of this series for the preservation of wood via fossilization applies to the preservation of wood as fossil fuel: the former process involved silicification; the latter, pyrolysis.

Problems remain in explaining how the enormous deposits of fossil fuels may have formed in the Williston Basin; however, many of these problems result from petrified thinking—blind adherence to belief in deep time, uniformitarianism, and evolution. Plausible explanations are more readily found from the diluvial perspective.

Acknowledgements

Klevberg thanks his employer for use of the company truck in roaming western North Dakota over several seasons and coworkers and others for information on the composition of Bakken crude. *Deum laudamus* (Proverbs 8:28).

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Glossary

allochthonous—formed by processes operating elsewhere, transported and deposited where now found.

autochthonous—formed in place by processes that acted where the deposit is now found.

bitumen—organic matter that is soluble as opposed to the insoluble portion, which is kerogen.

Darcy's Law—relation between hydraulic head, hydraulic conductivity, and average rate of flow of a fluid through a porous medium (Q = -k•dx/dy).

Deluge—the unique global flood cataclysm described in Genesis (*mabbul* in Hebrew).

diluvialist—one who believes the Deluge was the salient geologic event in Earth history.

isochronous horizon—a plane or surface representing a single time in the past which may cut across sedimentary features, such as the growth of a delta with subsequent deposits at the same level as previous ones.

kerogen—organic matter in sediments that is insoluble in common organic solvents but which may release hydrocarbons upon heating. See Table II.

pyrolysis—breakdown of large organic molecules in kerogen from heating, producing mobile molecules with shorter carbon chains (petroleum) and releasing hydrogen, nitrogen, oxygen, and sulfur to leave carbon-rich insoluble material (coal).

Appendix

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