Thoughts on Gasoline Prices and The Bakken Shale

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27 May 2011

Background

This whitepaper summarizes my thoughts about an e-mail I have received every few months for the last year or so. The latest version stated the following (color and bold highlights are my addition):

> ———————— Original Message ————————-
>
> Subject: Fwd: .**Be sitting down when you read this**
>
> *You "will" pay **$5 a gallon +** again and you won't complain loud enough to make a difference, RIGHT!** ** *
>
> * **Here's an astonishing read. Important and verifiable information :** ** ** *
>
> About 6 months ago, the writer was watching a news program on oil and one of the Forbes Bros. was the guest. The host said to Forbes, "I am going to ask you a direct question and I would like a direct answer; how much oil does the U.S. have in the ground?" Forbes did not miss a beat, he said, "more than all the Middle East put together." Please read below.
>
> The U. S. Geological Service issued a report in **April 2008** that only scientists and oil men knew was coming, but man was it big. It was a revised report (hadn't been updated since **1995**) on how much oil was in this area of the western 2/3 of North Dakota, western South Dakota, and extreme eastern Montana ..... check THIS out:
>
> The Bakken is the largest domestic oil discovery since Alaska's Prudhoe Bay , and has the potential to eliminate all American dependence on foreign oil. The Energy Information Administration (EIA) estimates it at **503 billion barrels**. Even if just **10% of the oil is recoverable**... **at $107 a barrel**, we're looking at a resource base worth more than **$5...3 trillion**.
>
> "When I first briefed legislators on this, you could practically see their jaws hit the floor. They had no idea.." says Terry Johnson, the Montana Legislature's financial analyst.
>
> "This sizable find is now the highest-producing onshore oil field found in **the past 56 years**," reports *The Pittsburgh Post Gazette** *. It's a formation known as the Williston Basin , but is more commonly referred to as the 'Bakken.' It stretches from Northern Montana , through North Dakota and into Canada . For years, U. S. oil exploration has been considered a dead end. Even the 'Big Oil' companies gave up searching for major oil wells decades ago. However, a recent technological breakthrough has opened up the Bakken's massive reserves..... and we now have access of **up to 500 billion barrels**. And because this is light, sweet oil, those billions of barrels will cost Americans just **$16 PER BARREL**!
>
> That's enough crude to fully fuel the American economy for **2041 years straight**. And if THAT didn't throw you on the floor, then this next one should - because it's from **2006**!
>
> **U.. S. Oil Discovery- Largest Reserve in the World**
>
> **Stansberry Report Online - 4/20/2006**
>
> Hidden **1,000 feet** beneath the surface of the Rocky Mountains lies the largest untapped oil reserve in the world. It is more than **2 TRILLION barrels**. On **August 8, 2005** President Bush mandated its extraction. In **three and a half years** of high oil prices none has been extracted. With this motherload of oil why are we still fighting over off-shore drilling?
>
> They reported this stunning news: We have more oil inside our borders, than all the other proven reserves on earth.. Here are the official estimates:
>
> - **8-times** as much oil as Saudi Arabia
> - **18-times** as much oil as Iraq
> - **21-times** as much oil as Kuwait
> - **22-times** as much oil as Iran
> - **500-times** as much oil as Yemen
> - and it's all right here in the Western United States .
>
> HOW can this BE? HOW can we NOT BE extracting this? Because the environmentalists and others have blocked all efforts to help America become independent of foreign oil! Again, we are letting a small group of people dictate our lives and our economy.....WHY?
>
> James Bartis, lead researcher with the study says we've got more oil in this very compact area than the entire Middle East -more than **2 TRILLION barrels** untapped. That's more than all the proven oil reserves of crude oil in the world today, reports *The Denver Post** *.

Don't think 'OPEC' will drop its price - even with this find? Think again! It's all about the competitive marketplace, - it has to. *Think OPEC just might be funding the environmentalists?** *

Got your attention yet? Now, while you're thinking about it, do this:

***Pass this along.** If you don't take a little time to do this, then you should stifle yourself the next time you complain about gas prices - **by doing NOTHING, you forfeit your right to complain**.** *

Now I just wonder what would happen in this country if every one of you sent this to every one in your address book.

By the way...this is all true. Check it out at the link below!!!

GOOGLE it, or follow this link. It will blow your mind.

http://www.usgs.gov/newsroom/article.asp?ID=1911

——————- End Original Message ————————-

http://www.usgs.gov/newsroom/article.asp?ID=1911

3 to 4.3 Billion Barrels of Technically Recoverable Oil Assessed in North Dakota and Montana's Bakken Formation—25 Times More Than 1995 Estimate—

Released: **4/10/2008 2:25:36 PM** Contact Information: U.S. Department of the Interior, U.S. Geological Survey Office of Communication

Reston, VA - North Dakota and Montana have an **estimated 3.0 to 4.3 billion barrels** of undiscovered, technically recoverable oil in an area known as the Bakken Formation.

A U.S. Geological Survey assessment, released April 10, shows a 25-fold increase in the amount of oil that can be recovered compared to the agency's **1995 estimate of 151 million barrels of oil**.

Technically recoverable oil resources are those producible using currently available technology and industry practices. USGS is the only provider of publicly available estimates of undiscovered technically recoverable oil and gas resources.

New geologic models applied to the Bakken Formation, advances in drilling and production technologies, and recent oil discoveries have resulted in these substantially larger technically recoverable oil volumes. **About 105 million barrels** of oil were produced from the Bakken Formation by **the end of 2007**.

The USGS Bakken study was undertaken as part of a nationwide project assessing domestic petroleum basins using standardized methodology and protocol as required by **the Energy Policy and Conservation Act of 2000**.

The Bakken Formation estimate is larger than all other current USGS oil assessments of the lower 48 states and is the largest "continuous" oil accumulation ever assessed by the USGS. A "continuous" oil accumulation means that the oil resource is dispersed throughout a geologic formation rather than existing as discrete, localized occurrences. The next largest "continuous" oil accumulation in the U.S. is in the Austin Chalk of Texas and Louisiana, with an undiscovered **estimate of 1.0 billions of barrels** of technically recoverable oil.

"It is clear that the Bakken formation contains a significant amount of oil - the question is how much of that oil is recoverable using today's technology?" said Senator Byron Dorgan, of North Dakota. "To get an answer to this important question, I requested that the U.S. Geological Survey complete this study, which will provide an up-to-date estimate on the amount of technically recoverable oil resources in the Bakken Shale formation."

The USGS **estimate of 3.0 to 4.3 billion barrels** of technically recoverable oil has **a mean value of 3.65 billion barrels**. Scientists conducted detailed studies in stratigraphy and structural geology and the modeling of petroleum geochemistry. They also combined their findings with historical exploration and production analyses to determine the undiscovered, technically recoverable oil estimates.

USGS worked with the North Dakota Geological Survey, a number of petroleum industry companies and independents, universities and other experts to develop a geological understanding of the Bakken Formation. These groups provided critical information and feedback on geological and engineering concepts important to building the geologic and production models used in the assessment.

Five continuous assessment units (AU) were identified and assessed in the Bakken Formation of North Dakota and Montana - the Elm Coulee-Billings Nose AU, the Central Basin-Poplar Dome AU, the Nesson-Little Knife Structural AU, the Eastern Expulsion Threshold AU, and the Northwest Expulsion Threshold AU.

At the time of the assessment, a limited number of wells have produced oil from three of the assessments units in Central Basin-Poplar Dome, Eastern Expulsion Threshold, and Northwest Expulsion Threshold. The Elm Coulee oil field in Montana, discovered in **2000**, has produced **about 65 million barrels of the 105 million barrels** of oil recovered from the Bakken Formation.

Results of the assessment can be found at http://energy.usgs.gov.

——————- End Linked Message ————————-

Notice how you need to **be sitting down** to read this information "quoting" a **2008** USGS report. Like most e-mails we are asked the forward to our friends, there are truths, half-truths, and outright lies. The first half of the e-mail talks about **503 billion barrels** (saying 10% is recoverable, or **50.3 billion barrels**), the second half of the e-mail refers to **2 Trillion barrels**, or 4 times the amount of oil in the first half of the e-mail, and they refer to **http://www.usgs.gov/newsroom/article.asp?ID=1911**, quoted above, which specifies **3-4.3 billion barrels** with a mean of **3.65 billion barrels** of oil. I start my comments off by noting that **3.65 billion barrels** of oil is a lot less than **50.3 billion barrels**, which is an awful lot less than **503 billion barrels**, and which is much less than 1% of **2 trillion barrels** of oil (about 0.18%).

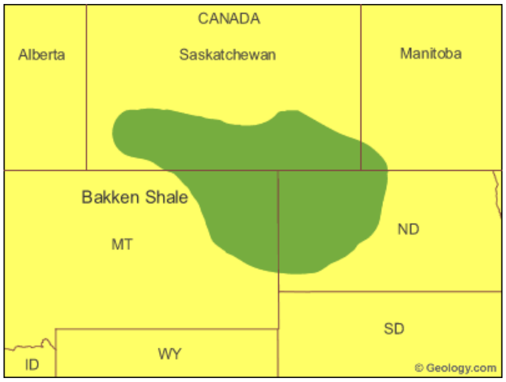

Figure 1: Extent of the Bakken Shale Play

The Bakken Shale

Oil and natural gas are generally believed to be generated from biotic karogens, organic material deposited in ancient rocks. When these karogens are buried deep enough in the earth, they are cooked by the temperature coming up from the center of the earth and the pressure of the rocks stacked above them. When the karogens crack and convert to oil and natural gas molecules, they are lighter than water, and their goal is to move upwards towards the atmosphere. This migration process moves the oil and gas through different types of rocks.

In oil and gas exploration, there are three key types of rocks:

1. source rocks, which are organic rich, like shales, and which provide hydrocarbons to the system;
2. reservoir rocks, which typically have good porosity (pore space, say between grains of beach sand, where hydrocarbons can collect after the plant material is cooked enough by subsurface temperatures and pressures to "crack" and become liquid oil or natural gas) and permeability (connection between the pore spaces filled with hydrocarbons); and
3. seal rocks, which have very little porosity and permeability, like salt and shales, and which keep liquid or gas hydrocarbons, which are lighter than water, from moving up towards the atmosphere.

The Williston Basin is an intercratonic basin. This sag in the North American Plate could be due to a failed rift system, like the Mid-Atlantic Ridge. The Williston Basin dates back 3 billion years ago. Erosion on the edge of the basin resulted in sedimentary deposits in the center of the basin. The oldest sedimentary rocks are the Paleozoic Cambrian Deadwood Formation dating back 490-520 million years ago. During ice ages the basin was covered with glaciers and there was no deposition. During times of global warming the basin was covered with deep water, and the sedimentary deposits were deep water shales. The Bakken Shale was deposited during one of these times of global warming when deep water covered the basin and sediment fill was full of organic material.

Figure 1 shows the modern day extent of the Bakken Shale in the center of the Williston Basin. There were extensive amounts of organic material deposited in the Williston Basin during this geologic time. Then, as the oceans receded, reefs grew, and the extensive Red River, Stony Mountain, Stonewall, Interlake, Lodgepole, Mission Canyon, and Madison reefs grew in various parts of the Williston Basin. As the oceans receded more, the Williston Basin turned into the equivalent of the Great Basin or the Dead Sea, and a thick layer of salts and evaporites were deposited on top of these ancient reefs and the Bakken Shale. Salt and evaporites are a very good seal and have kept hydrocarbons generated over geologic time trapped beneath them.

The Bakken Shale is one of several source rocks, known as resource plays, found around the globe which can act as a reservoir rock and as a seal rock. New horizontal and fracking drilling technologies have made it possible to produce from organic rich shales. Horizontal wells in the Bakken Shale will drill down vertically

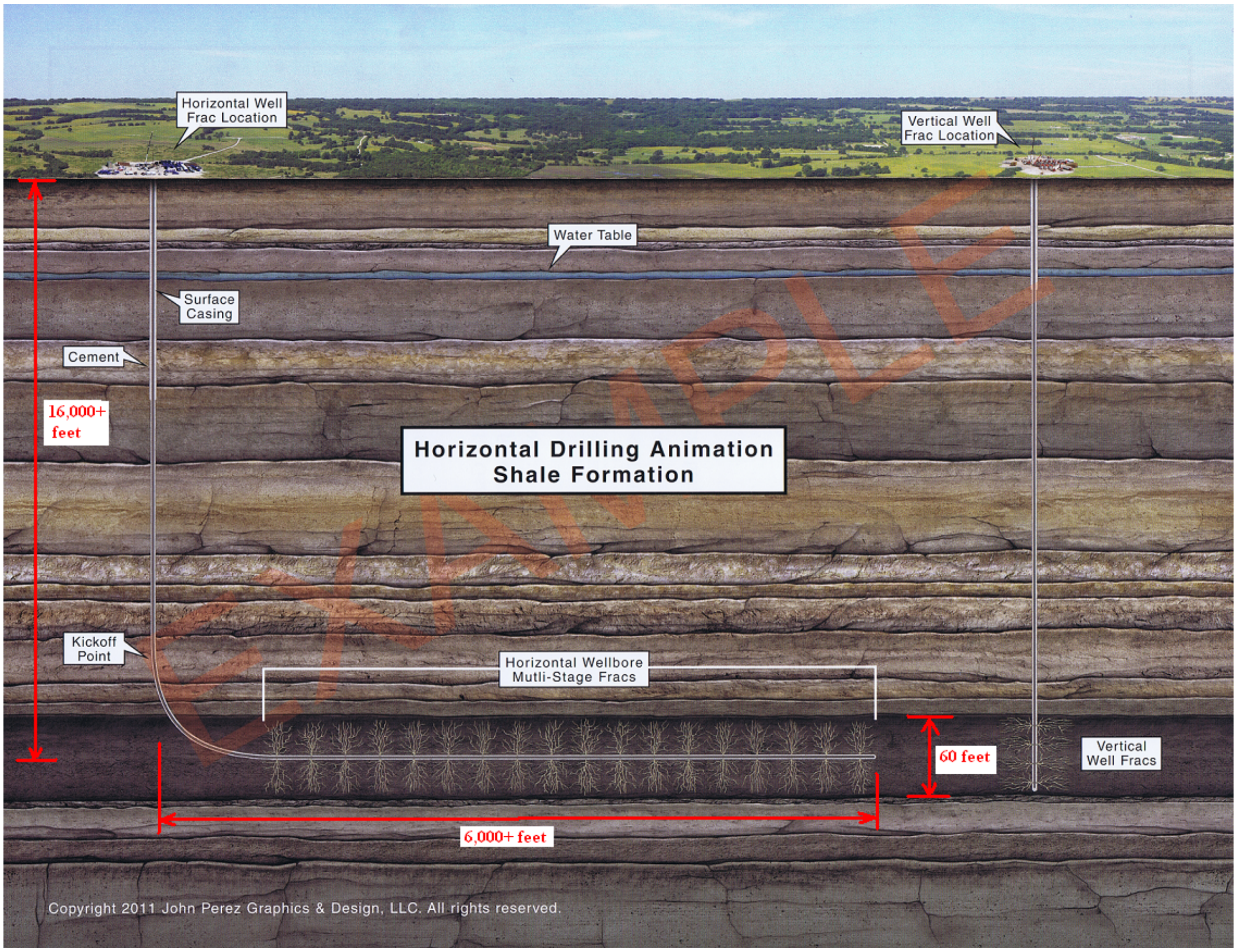

Figure 2: Horizontal Well Schematic from copyrighted advertisement

over 16,000 feet, then kick off and go horizontal over 6,000 feet staying within the 40-100 foot thick Bakken Shale. The borehole is cemented and sand and fracking fluids are pushed into the formation under high pressure to fracture the Bakken Shale. This fracking process increases the porosity (space between the pores) and the permeability (connection between these spaces) sufficient to allow turning this source and seal rocks into a reservoir rock. In the Williston Basin it is common to do 20 stage fracs. It costs $5-6 million to drill a 20 stage frack horizontal well. Figure 2 is a copyrighted drawing which nicely illustrates the process of horizontal wells and fracking.

If fracking is done too close to the surface, the new fracture porosity and permeability can reach into shallow aquifers and allow methane to contaminate the water supply. This occurred in La Veta, Colorado because a company applied fracking technology to a shallow shale gas play. This is the basis of the environmental concerns and the lawsuits in New York and Pennsylvania. These concerns are having significant negative publicity on resource plays. These environmental concerns are not applicable to the Bakken Shale Play because the objective is so deep, is beneath the thick regional shale and salt which trapped the oil, and has virtually no chance of the fracking contaminating shallow aquifers. In other places these concerns can have validity.

These new drilling technologies resulted in the reevaluation of the potential of the Williston Basin by the USGS (United States Geological Survey), which reevaluation was the basis for the e-mail this white paper is responding to. Table 1 from the referenced USGS report is shown in Figure 3. The first thing to note from this table is the difference between the undiscovered potential of continuous resources and of conventional resources. About 1/10$^{\text{th}}$ of 1% of the projected undiscovered potential resources are conventional resources.

Table 1. *Bakken Formation, Williston Basin Province assessment results.*

[MMBO, million barrels of oil. BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. F95 represents a 95 percent chance of at least the amount tabulated; other fractiles are defined similarly. TPS, total petroleum system; AU, assessment unit]

	Total Petroleum System and Assessment Unit	Field Type	*Total Undiscovered Resources*											
			Oil (MMBO)				*Gas (BCFG)*				*NGL (MMBNGL)*			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Continuous Oil Resources	**Bakken-Lodgepole TPS**													
	Elm Coulee–Billings Nose AU	*Oil*	374	410	450	410	118	198	332	208	8	16	29	17
	Central Basin–Poplar Dome AU	*Oil*	394	482	589	485	134	233	403	246	10	18	35	20
	Nesson–Little Knife Structural AU	*Oil*	818	908	1,007	909	260	438	738	461	19	34	64	37
	Eastern Expulsion Threshold AU	*Oil*	864	971	1,091	973	278	469	791	493	20	37	68	39
	Northwest Expulsion Threshold AU	*Oil*	613	851	1,182	868	224	411	754	440	16	32	64	35
	Total Continuous Resources					**3,645**				**1,848**				**148**
Conventional Oil Resources	Middle Sandstone Member AU	*Oil*	1	4	8	4	1	1	3	2	0	0	0	0
	Total Conventional Resources					**4**				**2**				**0**
	Total Undiscovered Oil Resources					**3,649**				**1,850**				**148**

Figure 3: USGS Table showing Assessment Results

Conventional and Continuous Resources

What is the difference between conventional and continuous resources? Conventional resources are biotic hydrocarbons generated from organic material, which migrate from a source rock to a reservoir rock and are trapped by impervious faults or by sealing rock. Continuous resources are those which are being dynamically replenished from bypassed or deeper pays, and a few think this replenishment has possible contributions from deeper abiotic (non-biologic) sources of methane captured in the mantle when the crust cooled.

Dynamic replenishment occurs when the rocks are at sufficient depth they are hot enough and under enough pressure any remaining organic karogens in the rocks are being cooked and cracked and and converted into flowing liquids (oil) or natural gas. A classic example of this is the giant Elmworth Field north of the Williston Basin in Alberta, Canada. Elmworth produces natural gas from a source rock with very low permeability and porosity, where new natural gas is being produced to refill the reservoirs. This replenishment occurs faster than the traditional understanding of happening across the millions of years of geologic time. The Bakken Shale is also continuously regenerating oil. However, none of the Bakken Fields have been produced long enough to be able to quantify the rate of dynamic replenishment of this continuous resource.

One of the best documented cases of dynamic replenishment occurring in historical time is a refilling event in the late 1980's in the Eugene Island 330 Field offshore Louisiana. After discovery, this field had increased production until it reached a peak, and then went into natural decline. The decline in production is well understood for oil and gas fields in different geologic environments and is often directly related to the decline in pressure of the oil and/or gas field as hydrocarbons are produced. Then the refilling event occurred. Our interpretation of the event (see the first of many publications on this study of Eugene Island 330 by a research consortium called The Global Basin Research Network)[1] is there was a fluid pulse from deeper oil deposits which came up "the Red Fault" and partially refilled the reservoir. As the additional hydrocarbons came into the reservoir, it increased the pressure and temperature of the reservoir. The pressure increase was about 25%, after which the field went back into the same rate of pressure decline as prior to the refilling event. An important point on Eugene Island 330 is the structural closure could not have held the amount of hydrocarbons which have been produced. The physics of geological conditions where dynamic replenishment

[1] 'Data cube' depicting fluid flow history in Gulf Coast sediments, Roger N. Anderson (Columbia University), Lawrence M. Cathless III (Cornell University), and H. Roice Nelson, Jr. (co-founder Landmark Graphics Corporation), Oil and Gas Journal, 04 Nov 1991

occurs is well understood, and yet, like the significant increase in potential resources by the USGS for the Bakken Shale, the concept of dynamic replenishment as a hydrocarbon exploration strategy is not part of the industry conversation.

This dynamic replenishment phenomena is sometimes referred to as "Reserves Growth" in the oil and gas industry. Quoting M. K. Verma[2] "Reserves Growth is a term used to refer to estimated increases in the total technically and economically recoverable petroleum reserves of a field that commonly occur through time because (1) additional reservoir and geologic information leads to increases in estimates of hydrocarbons in-place of existing reservoirs or pools; (2) new reservoirs or pools are discovered in existing fields; and (3) improvements take place in the hydrocarbon recovery factor owing to better understanding of reservoir characteristics and behavior through use of 3D/4D seismic interpretation, better geophysical logging tools, and improved reservoir simulation techniques. Additionally, application of horizontal-well drilling technology and enhanced recovery methods improve the hydrocarbon recovery factors significantly, resulting in increased estimates of reserves, particularly in oil reservoirs." Even though Reserves Growth can be caused by Dynamic Replenishment, the concept is generally not yet recognized as a basis for either Continuous Resources nor for Reserves Growth.

The bottom line is there is some basis for consumers to be concerned about the amounts of reported hydrocarbon resources. However, there is no basis for concern, as presented in the e-mail quoted above and similar e-mails, that gasoline prices are artificially high because someone is underproducing a significant resource. In fact, it seems to me the motivation for e-mails like this is is to divert attention. Possibly it is sent by what some of my friends call "watermelon environmentalists," i.e. green on the outside and red on the inside. Maybe the purpose of the e-mail is simply to increase discontent with existing systems to create an opportunity for revolution and taking of control by king men. Maybe it is sent out by speculators, who want to drive up prices so they can sell and make a large profit.

Measurements

The implication behind the e-mail is there is a conspiracy to keep from optimally producing Bakken Shale oil. This implication is absolute baloney. First, the government does not produce oil and gas. Private industry produces oil and gas. Private industry produces oil and gas whenever a profit can be made. In the history of the mankind, there has never been an economic engine which runs better than capitalism when it is unfettered by government regulation and interference. Is there anyone reading this whitepaper who believes the government could go in with a group of government employees or soldiers and drill a 16,000 foot well with a 6,000 foot offset with a 20 stage frack? Nor that they could accomplish this at anything close to the cost for industry to drill a similar well? Based on military and entitlement expenditures, I do not think it is possible for the government to economically run an oil exploration company. Consider the current and projected situation as reported in Investor.com:

> North Dakota's oil output is running at **350,000 barrels per day**, according to its state Department of Mineral Resources. Some **250,000 barrels of that come from the Bakken Formation**.
>
> "The growth is from Bakken," said John Kingston, director of news at energy analyst Platts. Indeed, production has rocketed for the past six years.
>
> In 2005, North Dakota put out just **100,000 barrels per day**. How high can North Dakota's oil output rise? "My most rosy estimate is **900,000 barrels per day**," Kingston said.[3]

A more optimistic commentator in The Barrel states:

> The US' Bakken Shale oil field, which spans Montana and North Dakota, has become so prolific that at least one big independent operator there estimates industry's output potential there at a whopping **1.2 million b/d by year-end 2016**.
>
> That's a heck of a lot of oil for a play that was barely breathing six or seven years ago. And that figure is even higher than the **700,000 b/d** or so North Dakota officials were citing as a peak awhile back.

[2] M.K. Verma, Modified Arrington Method for Calculating Reserve Growth—A New Model for United States Oil and Gas Fields, U.S. Geological Survey Bulletin 2172-D, pdf.

[3] Investor.com, 23 Mar 2011, see http://www.investors.com/NewsAndAnalysis/Article/566923/201103231820/Bakken-Shale-Promises-Big-Oil-Production.aspx

> Continental Resources CEO Harold Hamm, presenting his estimate of a Bakken peak of **1.2 million b/d** at Platts' Rockies Gas & Oil Conference in Denver this week, said volume girth in the play is expanding by around **5,000-10,000 b/d per month**.
>
> Other Bakken statistics, courtesy of Hamm: roughly **3,600 horizontal wells** have been completed in the field to date "and we've just scratched the surface," he said. Industry is now **adding about 2,100 wells a year**. About **170 rigs are active in the play**. Production on **the North Dakota side of the field is around 360,000 b/d**, while Bentek Energy Senior Energy Analyst Jodi Quinnell said in a telephone interview that **adding in Montana output brings the total output figure for the play to around 410,000 b/d**. Bentek is owned by Platts.
>
> Moreover, Hamm said a recent Continental study of the field's potential calculated **recoverable oil potential of 24 billion barrels** with today's technology. That number is substantially more than earlier **US government estimates of as much as 4.38 billion barrels** a couple of years ago, and that was up from a trifling **151 million barrels in 1995**. There seems to be no question that the Bakken can deliver, production-wise. But pipeline-wise, crude takeaway presents a problem. With so much oil oozing out of the ground, the Bakken needs more of it. Building new lines and finding new markets for it are big issues on the minds of both operators and pipelines these days.[4]

This projection of **24 billion barrels** of recoverable oil potential with today's technology is over 5 times the USGS assessment estimate. However, it is less than half of the 10% of recoverable reserves the e-mail attributes to The Energy Information Administration. It is probably more important to realize with a total of **410,000 barrels per day** production from **3,600 horizontal wells**, the average production is less than **115 barrels per day**. At a price of **$100 per barrel of oil**, this provides an average income of **$11,500 per day** for an average well. Typical cost for a horizontal well with a 20 stage frack is about **$5,000,000**. This means the initial well cost takes over 430 days of production to pay back. A **20% profit**, which is much larger than most oil companies report, does not happen until there has been this level of production for a year and a half. Since 20% to 25% of all royalties go to mineral owners, and since there are significant transportation costs to get the oil out of North Dakota, **typical wells are lucky to produce a profit after a two year investment**.

Oil and gas exploration and production is a high risk operation, with considerable upside for those who are successful and just as large unmet expectations and even bankruptcy for most participants. If we could accurately measure all of the geological and geophysical and drilling and production and transportation and market constraints, then it would not be so risky. However, we can not make these measurements with as much accuracy as we want. This is why the oil business is a risky business, and not for the faint hearted. If everyone who was sent this e-mail invested in Bakken Shale wells, only a small percentage would receive a return on their investment. Based on recent stimulus activities, if the U.S. Government invested in Bakken Shale wells, there would be absolutely no return on the investment.

Geologic Models

What explorationists can do is make a reasonable geologic model. These models are made by integrating geological data (formation tops, well log interpretations, etc.), geophysical data (seismic, gravity, magnetics, electromagnetics, etc.), petrophysical data (image logs, lithology logs, etc.), engineering data (perforations, production rates, fluids produced, etc.), and any other other data we can find together into an earth model. Then based on this dynamically updated earth model, we can make predictions about what will be found.

We know what a cross-section through the Williston Basin looks like (see Figure 4). Experienced geologists have learned to look at this type of information and visualize geologic relationships. For instance, note the horizontal scale distance of 25 miles is about the same as the vertical distance of 1,000 feet on this cross-section. This means the vertical scale is expanded approximately 130 times the horizontal scale. The Williston Basin is basically flat, with very thin layers of rock filling up the intercratonic sag basin. An approximate scale was added to the right side of this cross-section to emphasize the vertical distance to sea level or surface topography from the Bakken Shale in the northern (shallower part) of the basin.

[4]The Barrel, 15 Apr 2011, see http://www.platts.com/weblog/oilblog/2011/04/15/bakken_shale_oo.html

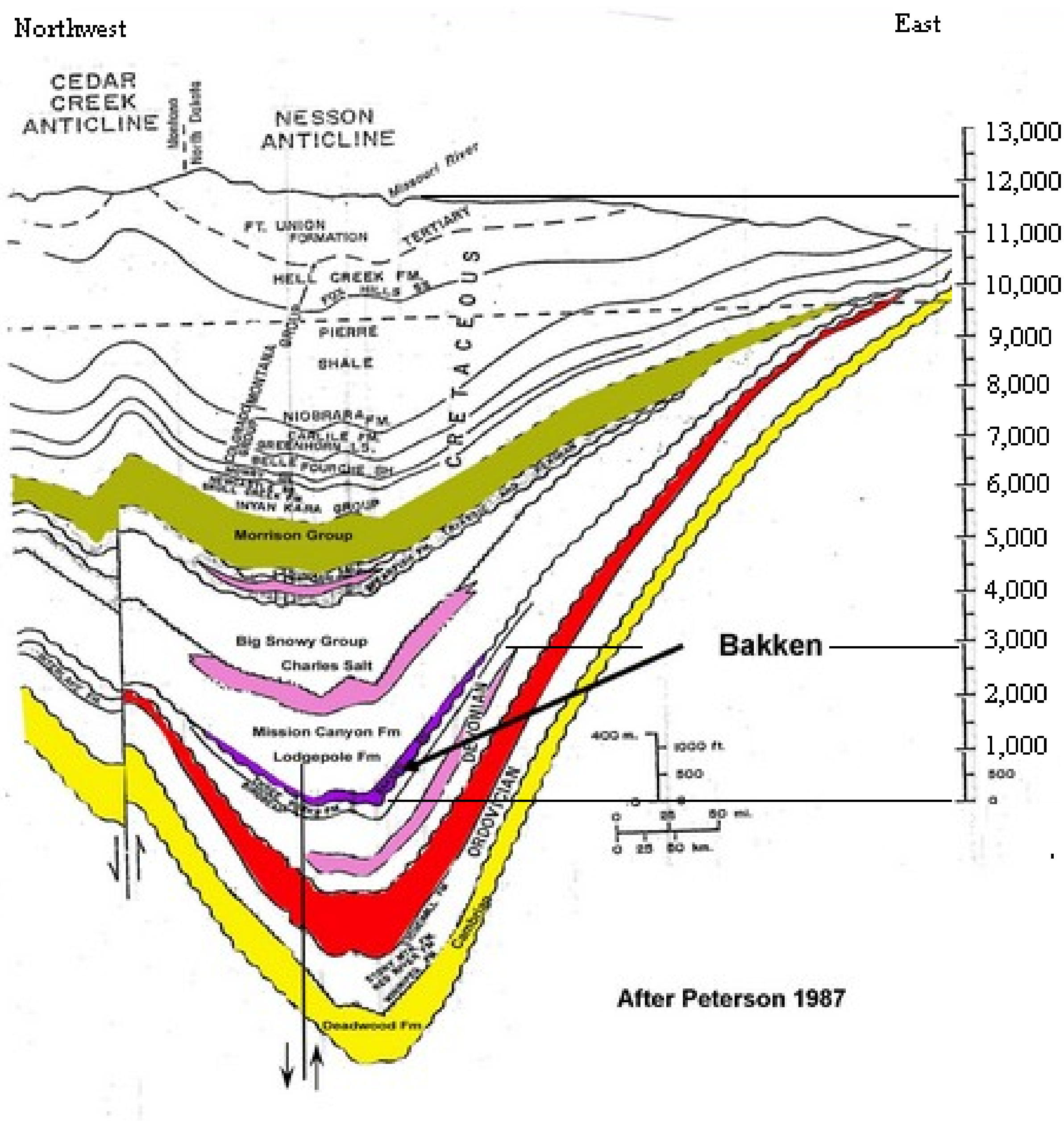

Figure 4: Williston Basin Cross-Section, Northwest corner of North Dakota Southeast and East

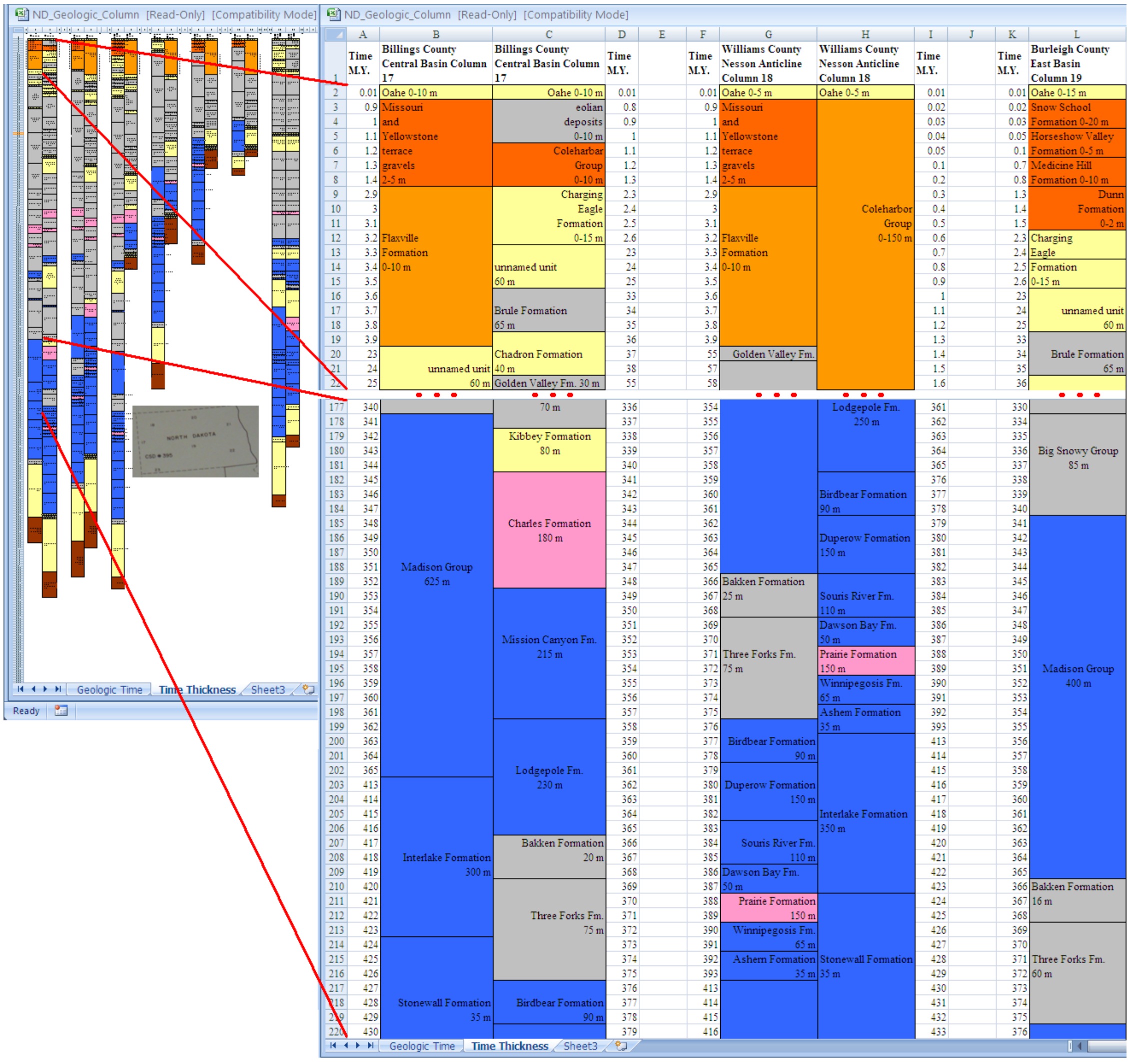

Figure 5: Geologic Time Section Showing the Bakken without Periods of Non-Deposition

There is extensive public domain information from the USGS, the North Dakota State Geological Survey, and other government and private organizations, which summarize results from wells which have been drilled in the Williston Basin and which can be integrated into the earth model. I made the next three figures to help define the geological model as part of a study of the Williston Basin I headed up in the fall of 2010 and spring of 2011. Figure 5 shows a geologic cross-section generated from specific wells drilled from western North Dakota to central North Dakota at the north end of the Nesson Anticline. This type of cross-section highlights the relative difference in well depths with geologic age and lithology details.

Figure 6 is an alternative display of this geologic data with blank intervals for geologic times, where either there was no deposition, or where the sediments have been eroded. This type of cross-section is useful in highlighting the relative thinness of the 45 to 75 foot thick Bakken Shale target.

What is not shown here is the fact the Bakken Shale is divided into three separate members, the Upper Bakken Shale, the Middle Sandstone Member, and the Lower Bakken Shale. All Bakken wells do not produce the same. Wells that drill into the Upper or Lower Bakken Shale tend to not produce enough oil to cover the cost of drilling the wells. Where the Middle Sandstone Member has more sand, if the drillers can keep the drill bit within this **15-25 foot interval** at over **16,000 foot depth** and with over **6,000 feet of horizontal drilling**, and if the fracking process is successful, the wells can be very successful, and a nice profit can be made. These areas with better porosity and permeability are referred to as sweetspots.

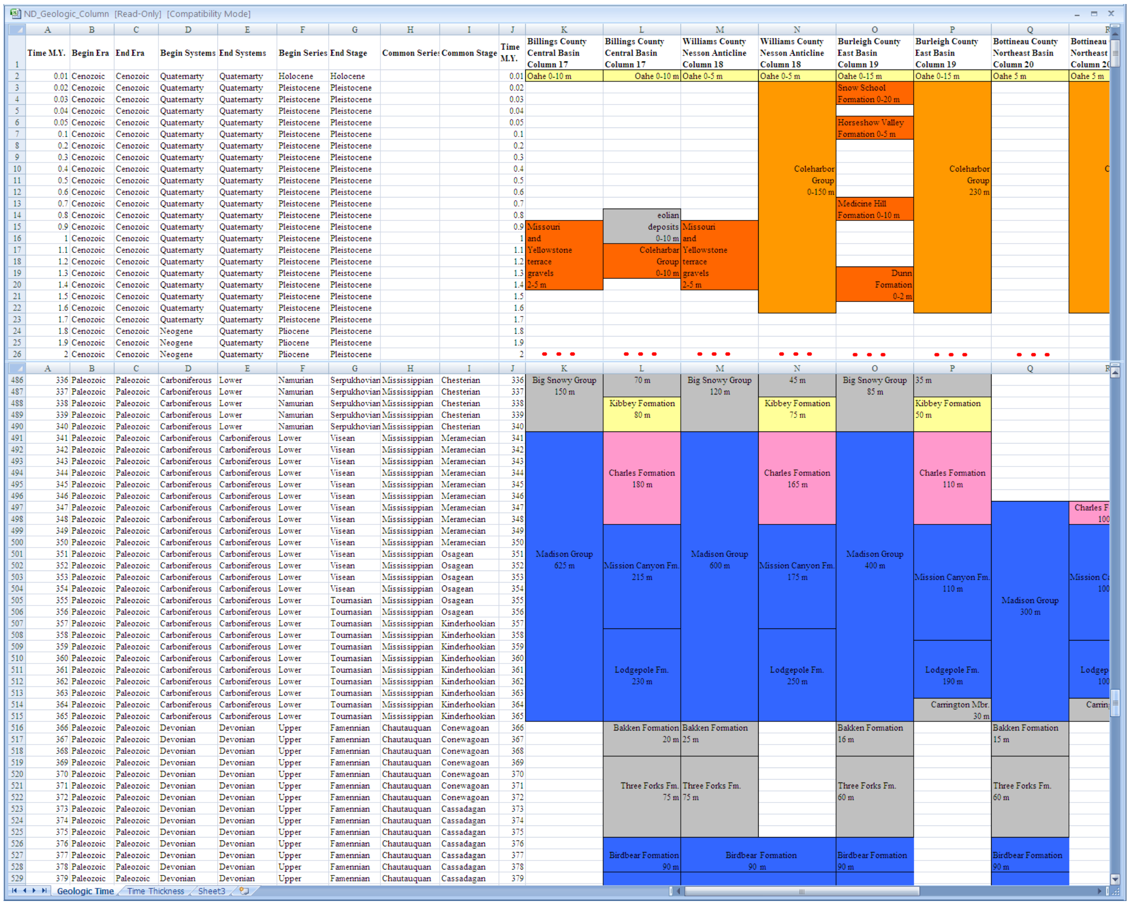

Figure 6: Geologic Time Section Showing Bakken Geologic Time and Thickness

Another type of Bakken Shale sweetspot is associated with reactivation tectonics. Basement fault blocks form patterns which can be mapped with aeromagneitcs and other geophysical tools. In places like around Toronto, Canada, where the basement rocks outcrop, these fracture systems can be studied from air photographs and satellite images. Whenever there is a major earthquake, like the large Japanese earthquake, the earth rings like a bell, and these basement faults are reactivated. In intercratonic basins, like the Williston Basin, where the sedimentary rocks are very old and very brittle, when the basement faults move, the faults crack the rocks directly above. These faults tend to be almost vertical, and as such are very hard to identify using geophysical tools like seismic. One of the most active periods of reactivation tectonics in the Williston Basin was during the Laramide Orogeny, when the Rock Mountains west of Denver were thrust up. Far field stress faults in the Williston Basin created structures like the Nesson Anticline. These vertical fault movements have tremendous amounts of force behind them, which shatters the old hard brittle rock next to the reactivated faults. This shattering creates another type of sweetspot, one based on fracture porosity and fracture permeability. This sweetspot is not generally recognized in Bakken Shale exploration and exploitation.

Well bores and geophysical measure vertically. Stratigraphy, the study of the process by which sedimentary rocks are deposited in a basin, is largely concerned with the horizontal extent of geologic processes. Well logs, seismic traces, magneto-telluric traces and other geological and geophysical measuring tools measure vertical changes in geology. One of the key contributions of 3-D seismic surveys is the fact these one-dimensional vertical measurements (seismic traces) cover a large enough area interpreters can evaluate the horizontal extent of structural blocks and stratigraphic depositional processes. An issue is the fact most 3-D seismic surveys are very small compared to the extent of stratigraphy changes. The Bakken Shale was deposited throughout the center of the basin, across tens and hundreds of thousands of square miles. The

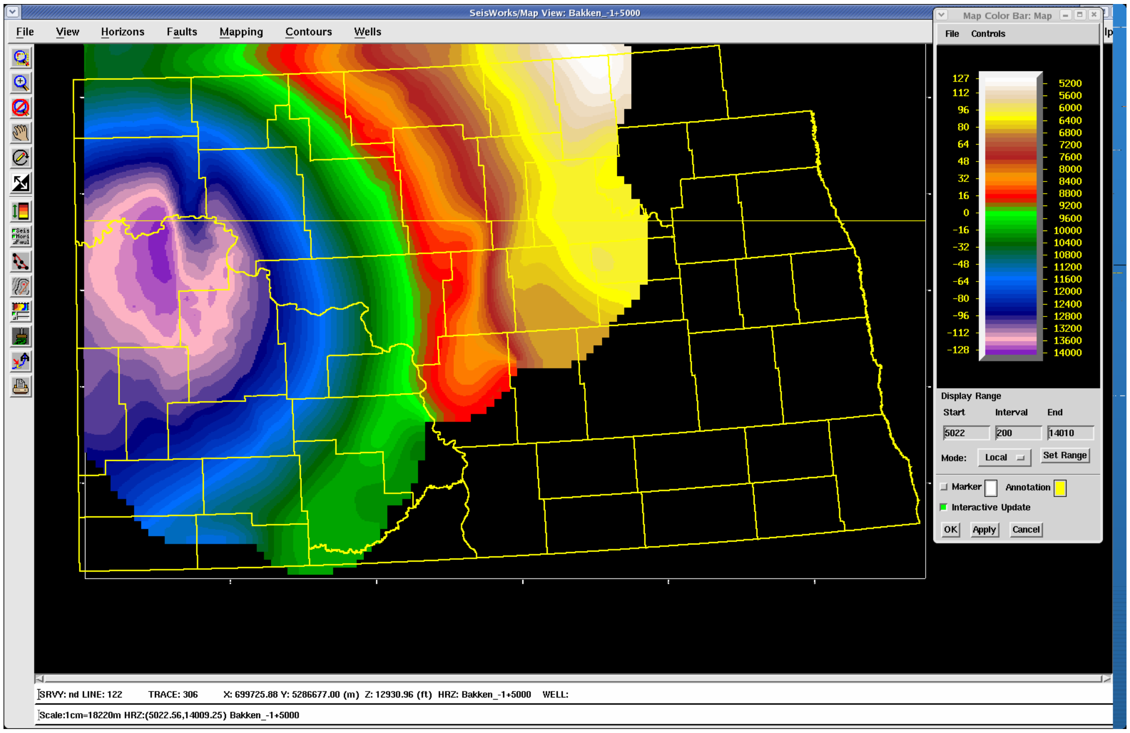

Figure 7: Depth to the Bakken in North Dakota from a sea level datum

3-D seismic surveys are particularly useful in showing where this 40-100 foot layer of rock is faulted up or down, sometimes 20 feet and sometimes 250 feet, because of basement fault block movement.

This horizontal scale is highlighted in Figure 7, a map showing the depth (TVDSS: True Vertical Depth Sub-Sea) to the Top of the Bakken Shale from a datum at Sea-Level, as mapped from Tops from the North Dakota Geological Survey. What this map does not show are the hotspots, or places where the Middle Sandstone Member is well developed, or where the Spanish Sands underneath the Bakken Shale are well developed and in a position where hydrocarbons will migrate out of the Bakken into these better reservoir rocks.

Existing Bakken Shale Drilling

Over 18,500 wells have been drilled in North Dakota, as shown in Figure 8. In one of our studies of the Williston Basin, we used 7,670 wells to analyze the Bakken Shale. We were able to use advanced geostatistical tools to identify underdrilled high probability of success areas for drilling the Bakken Shale. However, when we took it to companies to raise capital for leasing and drilling, we were told “You will not be successful, first because there are very leases available, and second because what the lease costs are too high for those leases available.” This was a first class exploration project, with specific drilling locations, each with an 80% probability of successfully tapping into a sweetspot, and we have not been able to sell it to to top management at companies with a 50 year history of exploring in the Williston Basin. Maybe if we sent out an e-mail full of inconsistent and irrelevant “facts” we will be more successful?

Note that at the scale of Figure 8 it looks like there are wells everywhere. Yet the e-mail in question implies nobody is looking in the Williston Basin, nobody is drilling the Bakken Shale, and nobody is really aware or this giant opportunity the USGS “suddenly” announced in their reassessment over 3 years ago. Again, capitalism works. Capitalism works better than any widesread economic system has ever worked in the history of mankind.

To be specific, in several places in the Williston Basin, like the Beaverlodge Field (see Figure 9), there are wells drilled on 40 acre spacing.

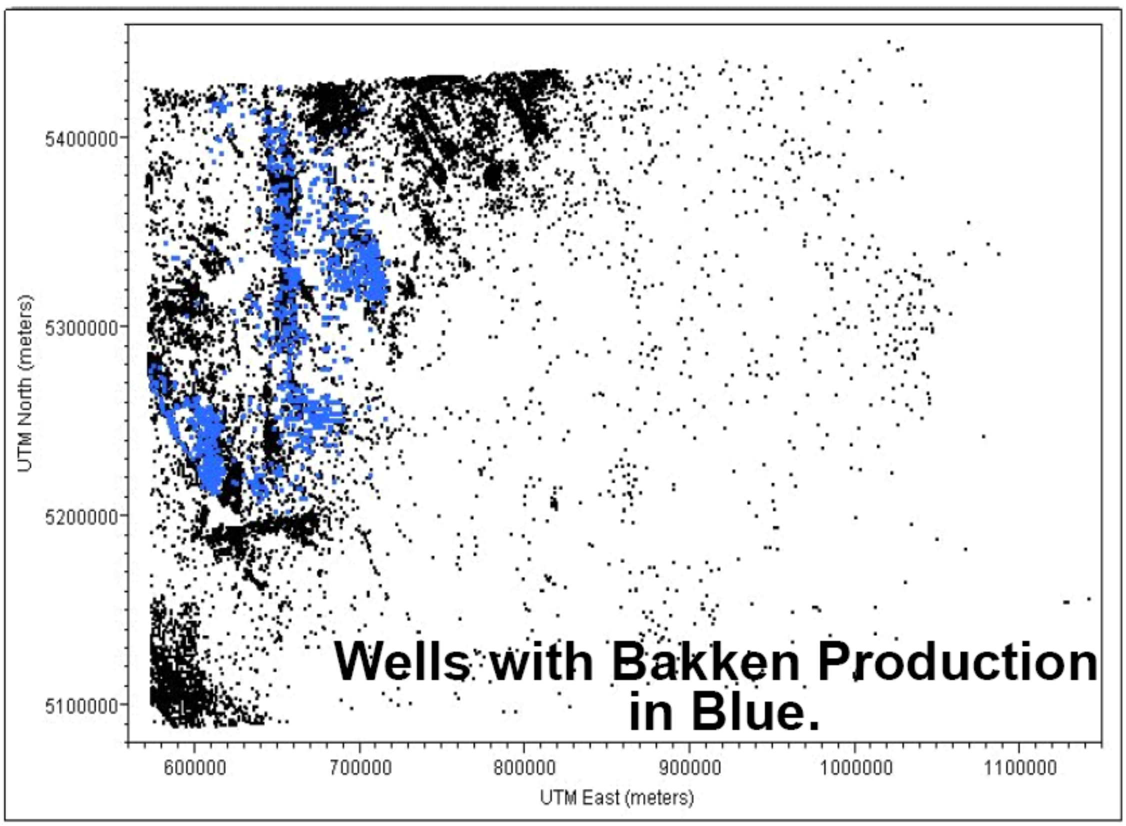

Figure 8: Wells Drilled in North Dakota

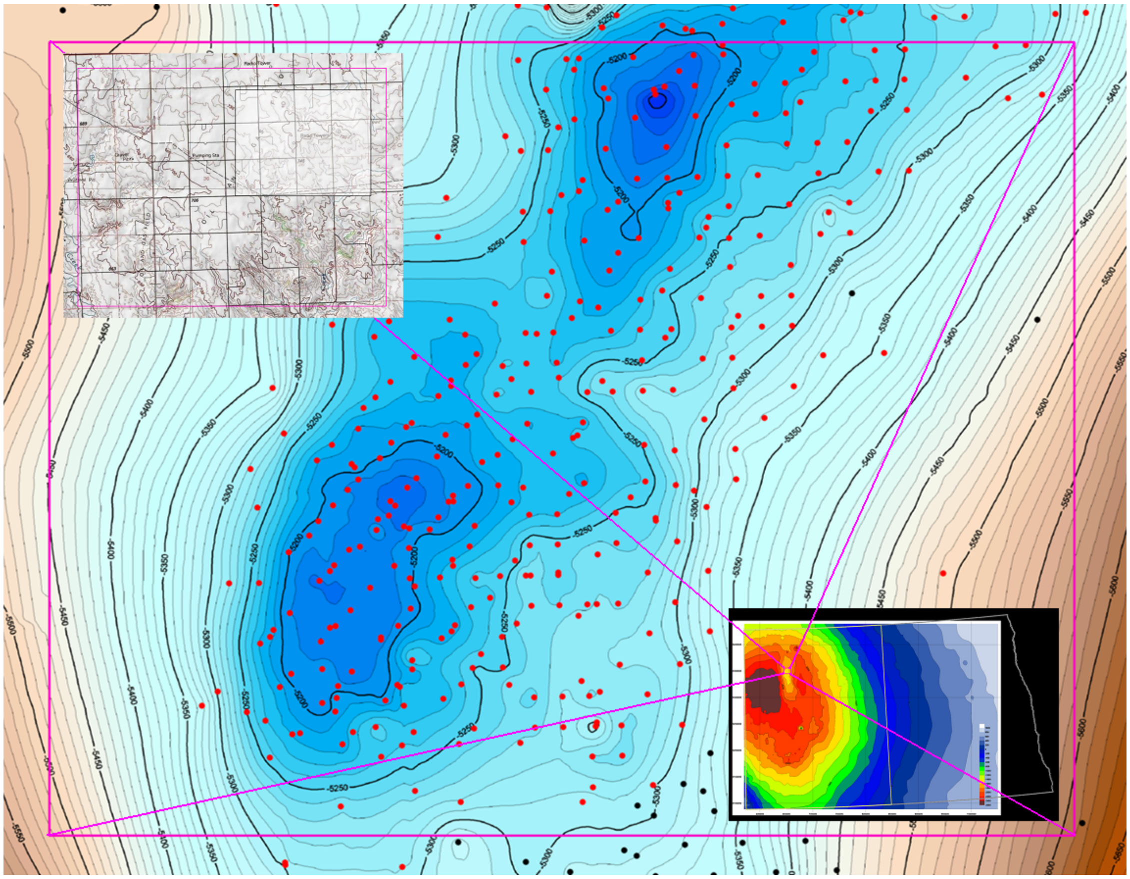

Figure 9: 40 Acre Well Spacing on map of the Top Madison over an 8 1/2 mile by 6 1/2 mile section of the Beaver Lodge Field, Williston Basin

The Bakken Shale is an understood exploration/exploitation opportunity. Lease and drilling and transportation and state tax costs are rapidly making it as marginally economic as most oil and gas exploration/exploitation opportunities. One exciting fact is there are new technologies being applied which are maximizing the probability of economic success. Specifically MicroSeismic Technology has developed passive seismic tools which allow them to listen to and map in 3-dimensional space plus time the microearthquakes created when a frack is performed. This mapping allows the operator to see when the sand and pressurized fluids being pushed out at a specific perforation dept are going into existing faults and when they are cracking open new micro-faults, faults which will create fracture porosity and permeability. When fracking fluids and sands go into existing faults, they do not enhance production. This is simply an unnecessary expense. By listening to the field and mapping microearthquakes through time the operator is able to optimize the intervals to produce. Adding microseismic studies to horizontal drilling and fracking technologies enables mapping of new sweetspots and enhances the probability of economic success.

Economic Impact of the Bakken Shale Play

As described above, the most economic Bakken Shale wells are drilled in either the Middle Member of the Bakken Shale or in naturally fractured sweetspots. Profit comes even after drilling a 20 frack horizontal well costs between **$5 million** and **$7 million**. Again, note that even at **$100 per barrel**, it takes at least **50,000 to 70,000 barrels** just to cover the drilling costs. This is a much different exploration model than drilling **$200,000** vertical wells in Saudi Arabia (at least 25 times less expensive than Bakken Shale wells) as part of a total exploration cost of **$2 to $4 per barrel** (between 10 and 50 times less expensive than Bakken Shale wells, depending on whose finding costs you use). As a specific example:

Marathon Oil plans to drill 120 to 145 wells in 2011, with 70 to 75 operated wells and 50 to

> 70 non-operated wells. The company estimates that its average well will cost from **$5.5 million to $6.5 million**, and produce an average of **300 to 500 BOE per day** during the first thirty days. The average well will have an estimated ultimate recovery of **350,000 BOE** per well.[5]

This news release says Marathon will recover on average **350,000 barrels of oil**, which at **$100 per barrel** is worth **$35 million**. Average drilling costs are **$6 million**, 25% lease lease is **$8.75 million**, transportation cost of over **$1 million** (**$3 per barrel**), 8 years (**350,00 barrels** at **115 barrels per day**) of operation costs is on the order of **$8 million**, and there is less than 6% annual return on investment. Overall though, it seems to make more economic sense to invest in Apple Computers, with their 30+% profit margin, than in a risky new oil and gas play like the Bakken Shale.

However, the state of North Dakota is not complaining, both based on unemployment rate and state budget surplus:

> ND's Oil Boom Has "has created a **$1 billion state budget surplus**": North Dakota, the state with the nation's lowest unemployment rate, capped a decade of economic prosperity with dramatic population growth in its biggest cities. ... North Dakota is enjoying an oil boom in the western part of the state, drawing workers from across the country. Williston, in oil country, grew 17.6% to 14,716.[6]

There are certainly factors I am not including in this cursory analysis. From the positive side, there are profits made downstream of exploration depending on how the hydrocarbons are used. From the negative side, there are transportation problems. For instance,

> One factor limiting production expansion is pipeline capacity, says Mark Williams, senior vice president of exploration and development at Whiting Petroleum (WLL). But even if no improvements are made to current infrastructure, **Bakken output could still rise to 600,000-800,000 barrels a day**, he estimates. However, there are designs for bolstering pipeline and rail infrastructure. "All current and planned projects could take us up to 1.1 million barrels a day," said Williams.[7]

Just a little evaluation makes one wonder why anyone exploring for oil and gas in the Bakken Shale. They are exploring because the Bakken Shale is a significant, relatively new, proven exploration opportunity. If all of the factors are properly analyzed and applied, there is an opportunity to be profitable.

Comparison of the Bakken Shale Play to other Exploration Plays

The e-mail estimates the oil resource relationship between several Middle Eastern countries and the Bakken Shale. This comparison is totally bogus. A quick review of the CIA World Fact Book shows:

- Saudi Arabia has an estimated **264.6 Billion Barrels** of proven oil reserves.
- Iraq has an estimated **115 Billion Barrels** of proven oil reserves.
- Kuwait has an estimated **104 Billion Barrels** of proven oil reserves.
- Iran has an estimated **137.6 Billion Barrels** of proven oil reserves.
- Yemen has an estimated **3.61 Billion Barrels** of proven oil reserves.

Compared to the USGS reassessment of the Bakken Shale of **3.65 Billion Barrels** of oil reserves, the only comparison is with Yemen. This is not a valid comparison, because Yemen reserves are proven, not a reassessment of potential reserves. Figure 10 shows an even more relevant graph. This graph is an estimate of daily production for Saudi Arabia (**9 million barrels per day** in 2011), Iraq (**2 million barrels per day** in 2011), Kuwait (**2 million barrels per day** in 2011), Iran (**3 million barrels of oil per day** in

[5] Bakken Shale Blog, 20 Feb 2011, see http://shale.typepad.com/bakkenshale/well-cost/

[6] USA Today, 17 Mar 2011, see http://www.usatoday.com/news/nation/census/2011-03-16-north-dakota-census_N.htm?csp=34news&utm_source=feedburner&utm_medium=feed&utm_campaign=Feed:+usatoday-NewsTopStories+%28News+-+Top+Stories%29

[7] Investor's Business Daily, 08 Feb 2011, see http://www.investors.com/NewsAndAnalysis/Article/562553/201102081930/US-Bakken-Oil-Output-Soaring.aspx

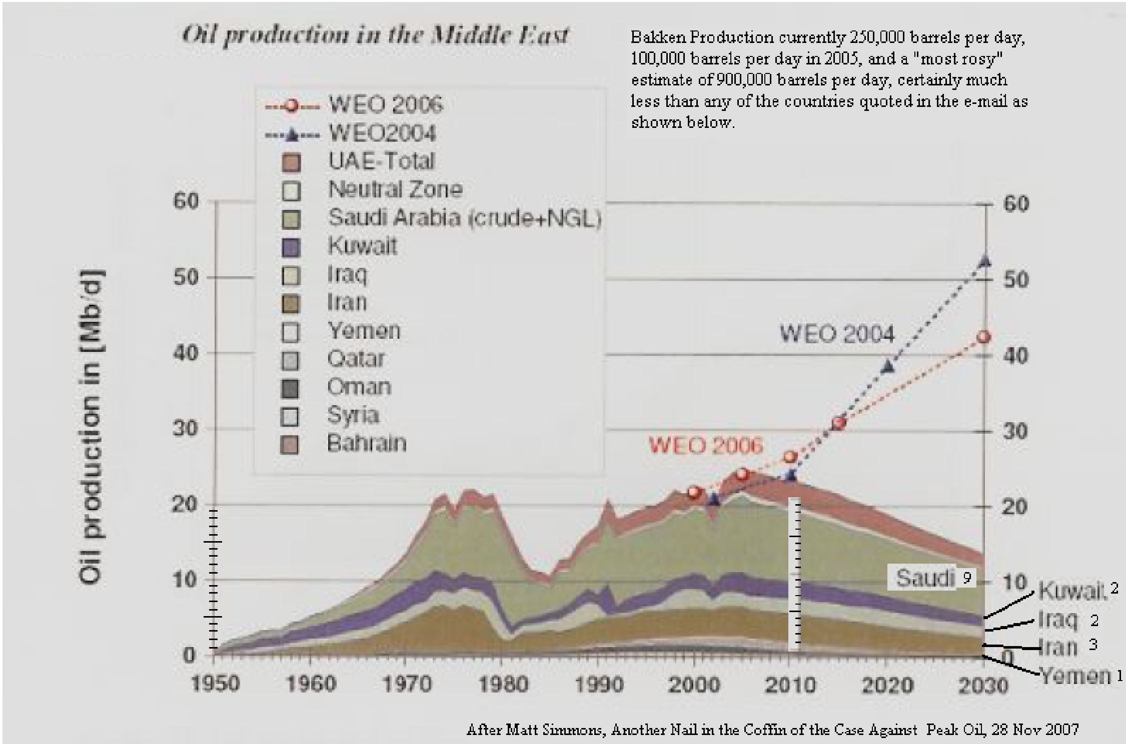

Figure 10: Comparing Bakken Production to Middle East Production

2011), and Yemen (**1 million barrels of oil per day** in 2011). Compare these production rates to the Bakken Shale (**0.25 million barrels of oil per day** in 2011 with a "most rosy estimate" of **0.9 million barrels of oil per day** by 2016).

Peak Oil

Figure 10 shows how oil production increases, drops off, and in the Middle East has increased again and dropped off again. The first drop off and second increase were largely driven by politics. In a free capitalistic market, there is an increase to maximum production, and then production drops off as the reservoirs deplete. This general trend is only overcome by new discoveries. New discoveries like the Bakken Shale discoveries, only much, much larger. If all **3.65 billion barrels** of Bakken resources could be put on-line today, and if all of the hydrocarbons could be produced in 10 years, it would result in annual production of **365 million barrels per year**, or **1 million barrels of oil per day**. I think this gives a perspective to the lack of value of the information in the e-mail.

This trend of increasing to maximum production, followed by a decline, is referred to as Peak Oil. The Peak occurs when a country produces more oil than it ever has before or more than it ever will in the future. As Figure 10 shows, the Middle East has probably past their peak oil production. This was certainly the theme of Matt Simmons book: Twilight in the Desert.

The concept of Peak Oil is simple. When an oil field is first discovered, it has not produced any hydrocarbons. The amount of production per year increases to a maximum, or peak amount of production. As the oil is produced the pressure drops and the amount of oil produced per year drops. This drop in production defines a decline cure. If time is the horizontal axis and the amount of production per year is the vertical axis, the decline cure looks like a lower case "n" with a long tail.

When the annual production of the sum of all of the oil fields in the U.S. is added up, it forms a normal distribution starting at "0" production per year in the late 1800's, when the first oil well was drilled in Pennsylvania, climbing to a peak in 1974, and dropping off ever since then, as shown in Figure 11. The year 1974 was the year the U.S. produced more oil than it every has or ever will. However, the demand for oil has

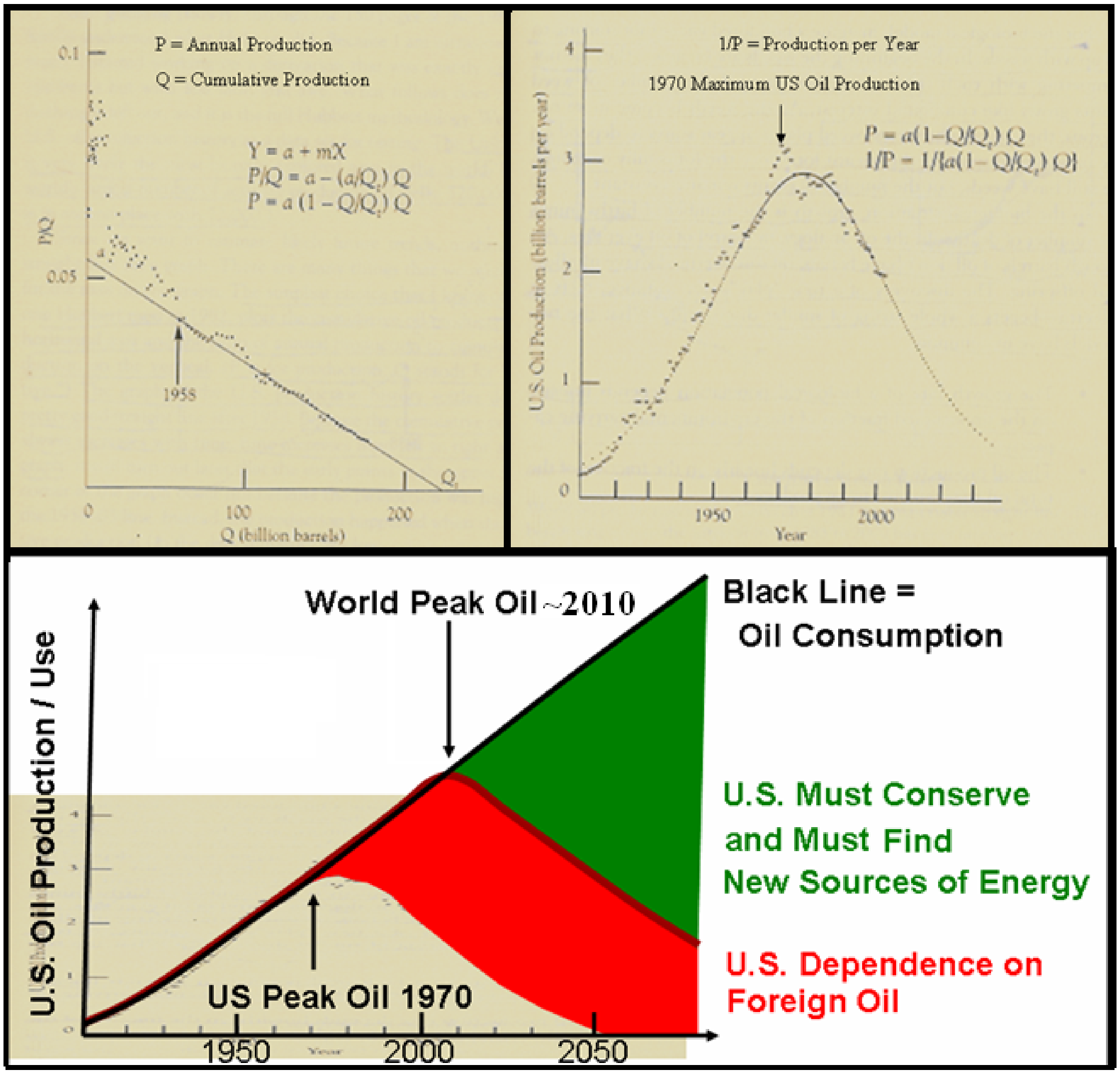

Figure 11: A Graphical Definition of Peak Oil: M. King Hubbert published this geostatistical summary of oil production in 1969.

continued to increase each year. The gap between demand and U.S. production, highlighted in red, has been provided by imports, and represents US dependence on foreign oil, the unintentional funding of terrorists, the over use of cars and trucks for cheap transportation, the spread of the suburbs, and a litany of other problems.

For the past few years the world oil supply curve has been flattening out, and is expected to continue to go slightly up and down. Then the world production of oil will start to fall off, just like the U.S. production per year fell off after 1974. The problem is there are not places to find new quantities of oil to meet consumption requirements. The oil and gas exploration and production industry really has been very effective in finding the large oil and gas deposits worldwide. The focus is in ultra deep water now, because they think they have found all of the large deposits in less hostile environments.

The gap between supply and demand is what is creating big problems, including high gasoline prices. Besides the physical limitations of the amount of oil available, there has been a significant impact on gasoline prices by future price speculation and hedge funds. Finding a way to manage the greed of these investors will have much more impact on lowering gasoline prices than sending out or forwarding inaccurate e-mails about the untapped potential of the Bakken Shale.

Figure 12 shows a total hydrocarbon production forecast from 1930 through 2050. This 2006 chart says the

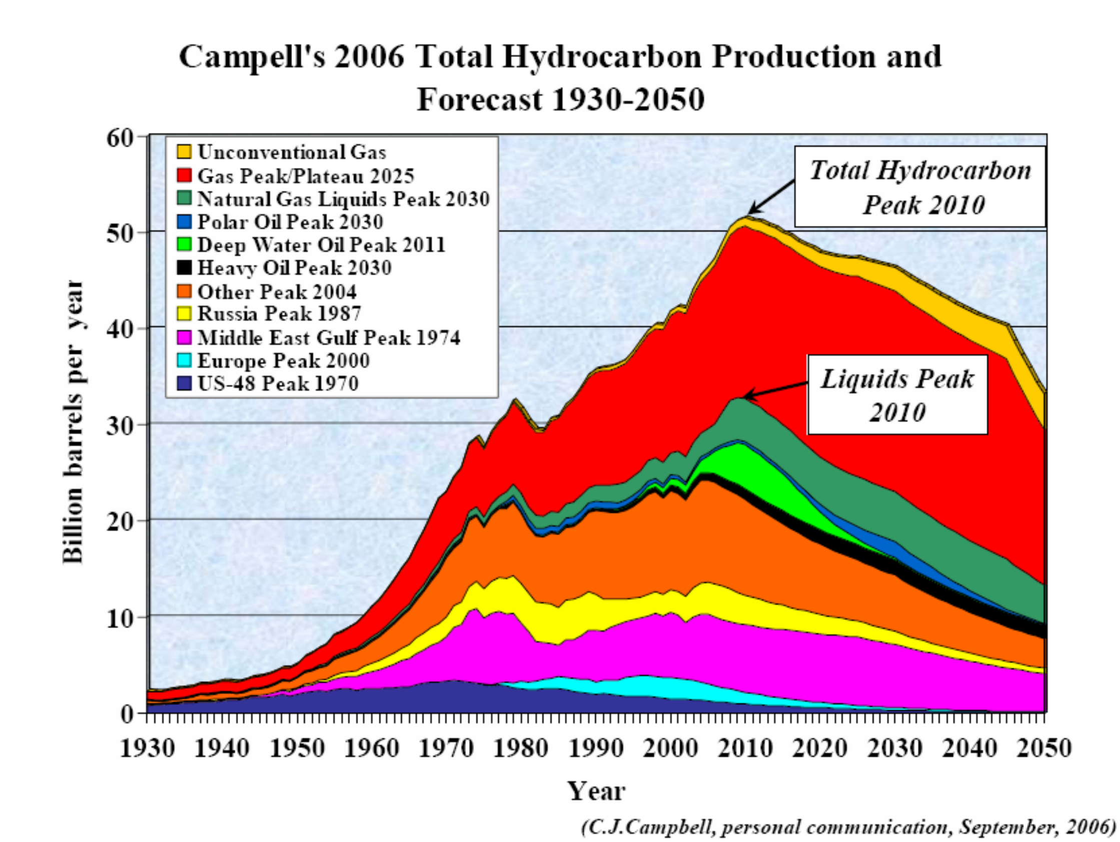

Figure 12: Hydrocarbon Production Forecast: David HughesGeological Society of Canada

world reached Peak Oil in about 2010. Because of the recession and significant new resource play discoveries, including the reassessment of the Bakken Shale, world peak oil has probably not occurred. However, the maximum production of oil is close. The peak production that is close is not the peak for hydrocarbons in general, and particularly not the peak for natural gas. The worldwide peak production of oil is close. Please note oil is where gasoline to run our cars comes from, where plastics, synthetics, pharmaceuticals, and the foundation for make-up comes from. Gasoline does not come from natural gas.

This concept of Peak Oil is why there is validity in the renewable energy discussion. However, current approaches to renewable energy are a joke. Figure 13 illustrates the problem. Oil, natural gas, and coal have and will continue to provide 80%-90% of energy consumption through the next few decades. Nuclear Energy provides a small contribution, and with the meltdown tied to the earthquake and tsunami in Japan this contribution is sure to fall off. Wind and solar provide a negligible contribution to energy consumption, dwarfed by hydroelectric and less than the contribution of geothermal energy. There are renewable options with better potential than either wind or solar.

It is important to note the approach to peak oil does not mean we are approaching peak natural gas. In fact, shale gas plays have had a major impact on when we will reach peak natural gas consumption. As a specific example, in the last decade the amount of gas projected as recoverable from the Marcellus Shale in and surrounding Pennsylvania and New York has gone from a few trillion cubic feet (TCF) of natural gas to estimates of over 500 TCF, with estimates of 50 TCF recoverable reserves. The CIA Fact Book says Saudi Arabia has 7.461 TCM of natural gas (263 TCF), or about half of amount of natural gas the Marcellus Shale alone is estimated to contain. A big issue is our society and infrastructure are not set up to use natural gas as a primary energy source. This needs to change, and e-mails to this effect can have much more impact than e-mails about how much oil there is in the Bakken Shale.

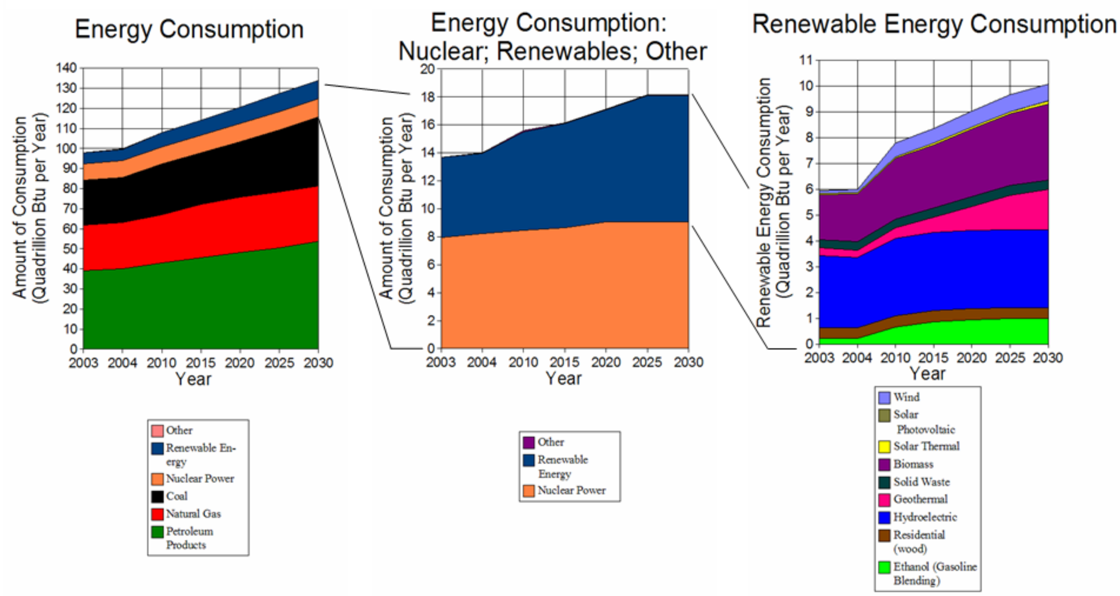

Figure 13: Relative Consumption of Traditional and Renewable Energy Sources

Gas Hydrates

To give a bit more perspective on the availability of natural gas, consider gas hydrates. Gas hydrates occur abundantly in both the permafrost of polar regions, and in deep marine sediments. Gas hydrates are a crystalline solid, typically consisting of a methane molecule surrounded by a cage of water molecules. Hydrates look like ice, and when melted creates potable water and natural gas. The USGS did a study of North Carolina and South Carolina and estimates there is 1,300 TCF of methane gas in two areas each about the size of the state of Rhode Island.[8] Note this is almost three times the amount of natural gas estimated to be in the Marcellus Shale. Figure 14 shows there are over 20 known gas hydrate deposits in deep water off of the continental United States.

On a worldwide scale the extent of gas hydrates is truly phenomenal, as shown in Figure 15. Especially note all of the known methane hydrates in the permafrost of northern Siberia. I have heard estimates that if you took all known hydrocarbon molecules on planet earth (oil, natural gas, coal, gas hydrates, etc.), over 90% of these hydrocarbon molecules would be tied up in gas hydrates. The issue is we do not know how to economically extract the natural gas from methane hydrates. It appears to require a mining process, rather than a drilling and fluid flow process. The most elegant solution I have heard was the use of large vacuums used to extract magnesium nodules from deep water. According to what I recall hearing, these vacuums were used to vacuum up gas hydrates offshore Australia, which were then piped into the Cooper Basin. As the slurry moved through the pipeline, the hydrates melted. The gas was bled off and was used to power pumping generators, and the melted water was used for irrigation.

[8]Dr. William Dillon, USGS, see http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html

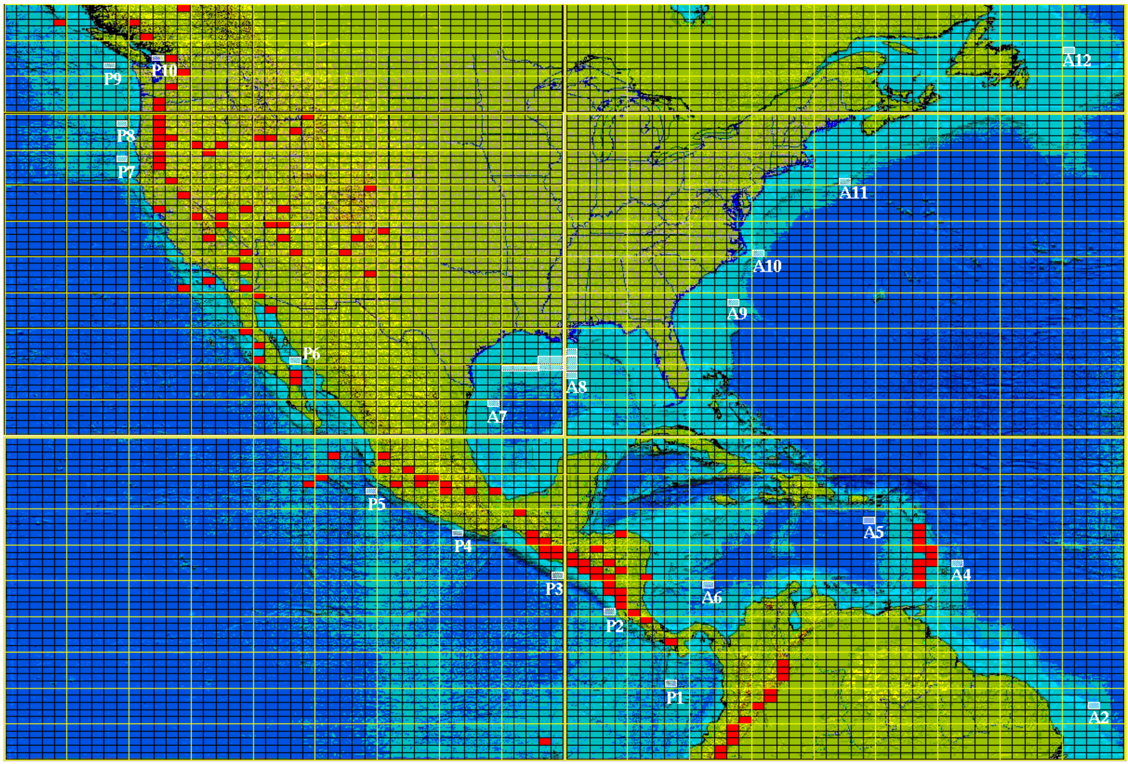

Figure 14: Gas Hydrates Around the Lower 48 States

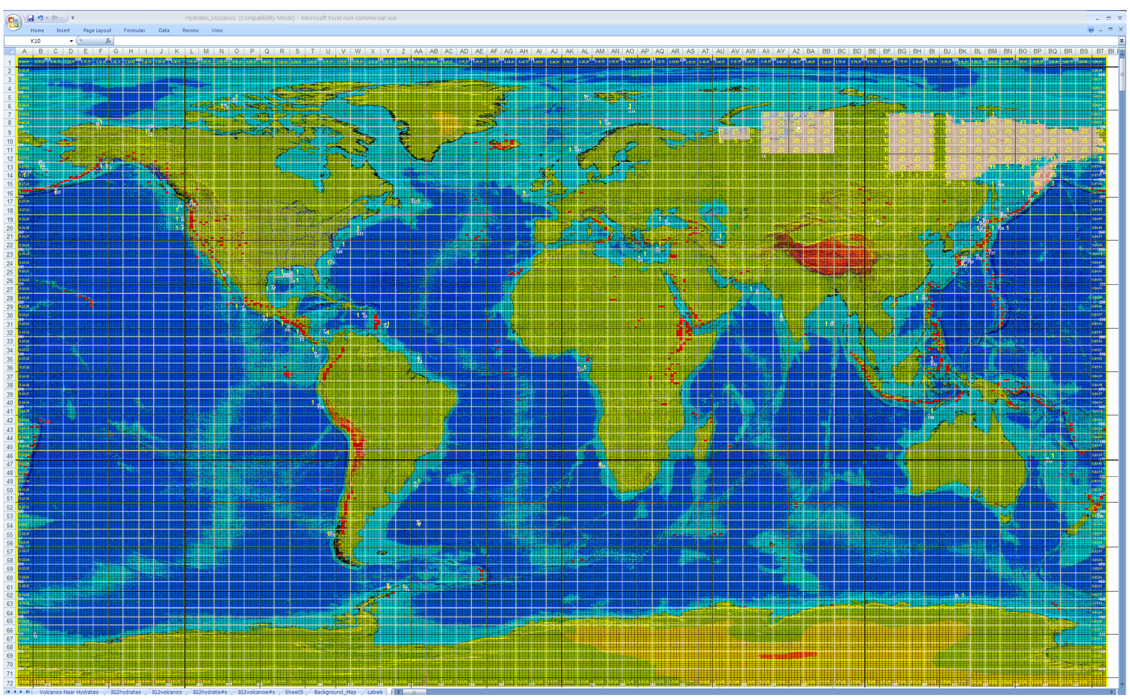

Figure 15: Gas Hydrates Worldwide

Conclusions

Rising gasoline prices are going to upset a lot of people. The e-mail about the potential of the Bakken Shale discussed in this whitepaper is a simple example of how uninformed people will over react. Even folks who are informed, like the Media, misrepresent the problem almost every night on the television. The Media talks about how much profit the oil companies are making with $100+ per barrel oil prices. The media has an agenda, and so they do not talk about ROI (Return On Investment). Oil industry profits were around a 7% ROI in 2010.[9] The media especially does not compare oil company ROI with the 38.5% gross margin for the first quarter of 2011 of their favorites like Apple Computers.

It is absolutely unfathomable to me how people can not see what is happening with regards to energy usage and misuse. The earth has been creating oil and gas for a few billion years. Mankind has been able to find and use a sufficiently large amount of this energy in less that the last 150 years to create a problem going forward. I love the way Buckminister Fuller put it in his 1981 book **Critical Path**:

> "The majority of Americans reach their jobs by automobile, probably averaging four gallons a day – thereby, each is spending four million real cosmic-physical-Universe dollars a day without producing any physical life-support wealth accredited in the energy-time – metabolic – accounting system eternally governing regenerative Universe. Humans are designed to learn how to survive only through trial-and-error-won knowledge. Long-known errors are, however, no longer cosmically tolerated. The 350 trillion cosmic dollars a day wasted by the 60 percent of no-wealth-producing human job-holders in the U.S.A., together with the $19 quadrillion a day wasted by the no-wealth-producing human job-holders in all other automobiles-to-work countries, can no longer be cosmically tolerated."[10]

Solutions are not easy, and yet solutions are possible. Solutions start with understanding the real problems and working to develop real solutions to these real problems. The e-mail about the Bakken Shale is hacking at the leaves. Rising gasoline prices are not the problem. Figure 16 shows some ways society is currently and will continue to react to rising gasoline prices.

There will be life on the otherside of the panic and conservation. However, it will be very different from the life we have known. For those interested I encourage you to review the 776 slide presentation I put together back in 2007 on "Replenishing the Earth or A Relationship Between Peak Oil, High Gasoline Prices, and L.D.S. Food Storage."[11]

Oil prices will climb from $100 per barrel to $200 per barrel. If not from simply supply and demand, from taxes to pay off the national debt. Future generations will consider our generation the most wasteful generation ever. They will read about our trips around the world with disdain. The entire world society will change because of a lack of cheap energy. Maybe we will choose to do innovative things like:

1. plant ethanol crops like sorghum cane or switchgrass on fallow subsidies, and stop using food (corn) for ethanol;
2. use algae as a source of ethanol;
3. turn the Alaskan pipeline rotation through the earth's magnetic field into an electricity generator;
4. connect the Asia and North American electric grids so solar generated electricity can power night time electric needs on the other side of the globe;
5. explore of dynamically replenishing oil and gas fields;
6. develop ways to mine and exploit gas hydrates;
7. built solar towers on mountain sides or in deviated well bores drilled down mountains to greenhouses at the base of the mountain where turbines generate electricity as hot air is sucked up the solar tower chimney;

[9] See http://www.huffingtonpost.com/social/DMDAY44/factchecking-the-oil-comp_b_864397_89073969.html
[10] R. Buckminster Fuller, Critical Path: Chapter 8, Critical Path: Part Two, page 262
[11] See http://www.walden3d.com/aspo/po/index.html

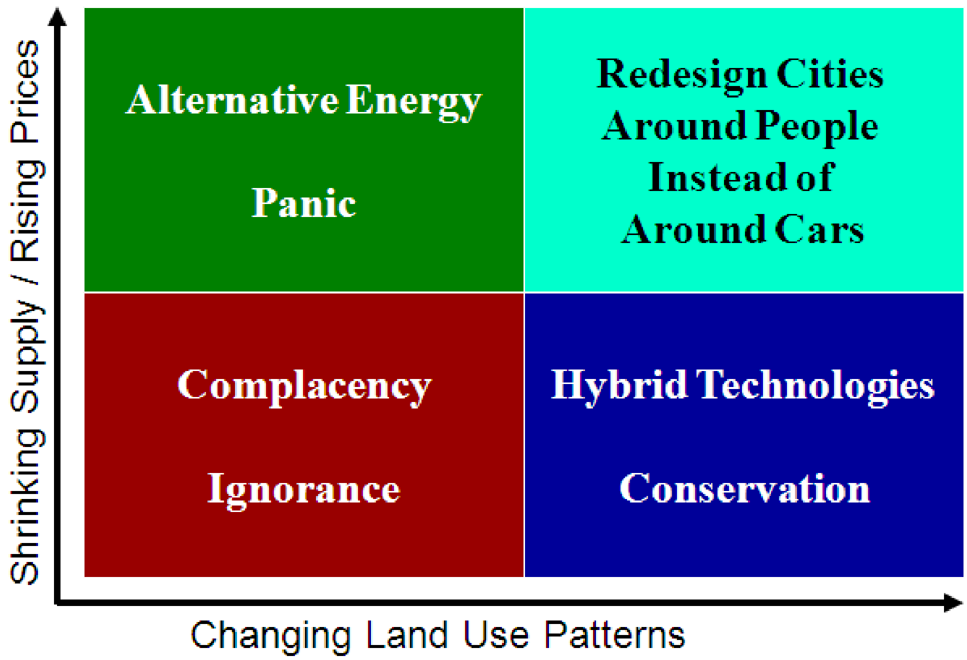

Figure 16: Societal Reactions to Rising Oil Prices

8. take better advantage of tidal and river power for electricity generation; and
9. redesign our cities around people instead of around cars, telecommuting more by taking better advantage of electronic communication tools.

There will always be oil and gasoline. There just will not be much more, if any more oil at $100 per barrel, nor gasoline at $4.00 per gallon. Gasoline prices are over $8.00 per gallon in Europe. I think we should expect the same in the U.S.A., and plan accordingly.

