A response to Jeff Goodell's article in April 2023 Rolling Stone

After reading the Rolling Stone article written by Jeff Goodell for the April 2023 issue and numerous other uninformed reviews of ReconAfrica, it is necessary to respond to misinformation and specifically to disinformation (i.e., wrong on purpose). For example, Mr. Goodell and others previously wrote that no one "would comment on the methodology behind calculations" (ref. the total petroleum generation potential). In fact, these calculations were supplied in full detail.

Much of the article draws on previously misinformed opinions from experts. What makes these persons experts? They may be experts in a particular field, but it is obvious they are not experts in petroleum geochemistry. However, the so-called experts who have petroleum experience truly demonstrate their lack of knowledge or purposeful misstatements. As such these so-called industry experts are, in fact, lacking credibility on facets of petroleum exploration despite having worked in the sector. It may be excusable for non-geochemists to lack knowledge on petroleum geochemistry, but these so-called expert's input as cited in the article is entirely misleading and advances their agenda. This is most apparent on, not only the geochemistry, but also with drilling strategies. It is well known that such negative campaigning is successfully applied particularly in politics, and this is obviously a political issue.

Part 1. Total Petroleum Generation Potential

It has been reported that the total petroleum potential calculated from the referenced source rock data is not feasible or worse a fabrication meant to misrepresent the petroleum potential of the Kavango Basin. This pessimism proves that many of these so-called industry experts do not have a clue about the generation of petroleum as opposed to what might be stored or trapped in a reservoir. The confusion between such reservoir calculations as original oil in place (OOIP) and the total petroleum generation are dramatic as only a small portion of generated petroleum is stored in any given reservoir.

The calculation is simple arithmetic although it does require a number of simple unit conversions and assumptions as to source rock potentials. In fact, there is industry software to perform a comparable calculation and is commonly used in basin modeling of petroleum systems.

When a variety of well-known source rocks that have been documented in detail are compared to the calculations for the Kavango Basin, they show even higher total petroleum generation potentials (Table 1). These source rocks have sourced numerous conventional plays and they all have been thoroughly analyzed and studied from core, cuttings, crude oils, and gases. Their average results from public domain data are shown in the table.

Although all of these source rocks have high yields in boe/acre-ft, there are important differences. The Wolfcamp is very thick, upwards of 1000 ft whereas the Bakken is typically less than 80 feet and is not highly converted in many areas of the Williston Basin. In terms of boe/af as well as yield per square mile per 100 ft of source rock, the calculated Kavango Basin source rock is less than these other major source rock systems. However, when coupled with source rock thickness and areal extent only the Wolfcamp and Marcellus exceed the calculated values for the Kavango Basin. And even though the U. and L. Bakken Shales have by far the highest generation potential, those shales are much thinner and less highly converted (less mature), and therefore will not have the very high total generation potential.

Table 1. TPGPs in boe/af and boe/section/100 ft for various source rocks

Comparison of Various Potential Source Rocks at same thickness and 100% conversion						
Estimated Values	**Kavango**	**Wolfcamp**	**Eagle Ford**	**Barnett**	**Marcellus**	**Bakken**
TOCo:	5.44	5.83	4.32	6.78	7.1	15.22
HIo:	358	510	619	434	490	687
S2o:	19.48	29.73	26.74	29.43	34.79	104.56
boe/af:	460	690	620	683	807	2426
boe/section/100 ft (mm boe/mile2/100 ft):	30	44	40	44	52	155

When the industry standard program, Kinex®, is used to calculate the Ultimate Expelled Petroleum and the Retained Petroleum the calculation yields approximately the same yield (29.4 mmboe/section/100 ft). The 100 ft of thickness is used for comparative purposes but provides an indication of yield per section (mile^2) per 100 ft of thickness. Obviously, if a source rock is thicker, it is simply a multiple of 100 ft.

When describing a specific reservoir where petroleum has been discovered, the description of original-oil-in-place (OOIP) is calculated, which is the amount of petroleum based on various geological, petrophysical and engineering principles. It is <u>always</u> much less than the total petroleum generation potential of the source rock or rocks.

One means to display petroleum generation potential is a simple plot to show the petroleum yield potential of source rocks. Figure 1 illustrates the potential petroleum yields (boe/af) for original HI vs original TOC for the selected source rocks in the table. Restored HI and TOC indicate the original HI and TOC, i.e., their values before any petroleum generation occurred. During petroleum generation, HI and TOC are both reduced. Because we often deal with mature source rocks, the original values have to be restored from the available data using trends derived from present-day (matured) values of HI.
You can see that the HIo used for the Kavango Basin is modest or conservative. The HIo is lower than most of these well-known source rocks to avoid overstating the petroleum generation potential. For reference HIo x TOCo = total petroleum generation potential (mg/g). Obviously, these laboratory units have to be converted into values that are useful such as barrels of oil equivalent per acre-foot (boe/af).

Note1: HI is the relative hydrogen content in a source rock and TOC is the total organic carbon; hydrocarbons are comprised of only carbon and hydrogen. "Original" means their values before any petroleum generation has occurred, i.e., immature (or not cooked). The subscript "o" designates this value.

Note2: The calculation of the amount of TOC that can be converted to petroleum is derived as the convertible (reactive) kerogen yield, i.e., original S2 (an abbreviation embedded in early geochemical literature but rather nondescriptive).

Total Convertible Kerogen = S2o = TOCo x HIo / 100 = mg of petroleum per gram of rock

Note3: For a given TOCo, the value for HIo determines the amount of kerogen that can be converted to petroleum, e.g., a HIo of 800 mg/g will have over 70% convertibility whereas a HIo of 200 mg/g will have only ca. 13% convertibility.

Note4: You have likely noticed that the term petroleum is used in lieu of oil or gas throughout this commentary. Petroleum consists of both oil and gas. Thus, when the abbreviation boe is used, it means oil and gas without description of the percentages of either.

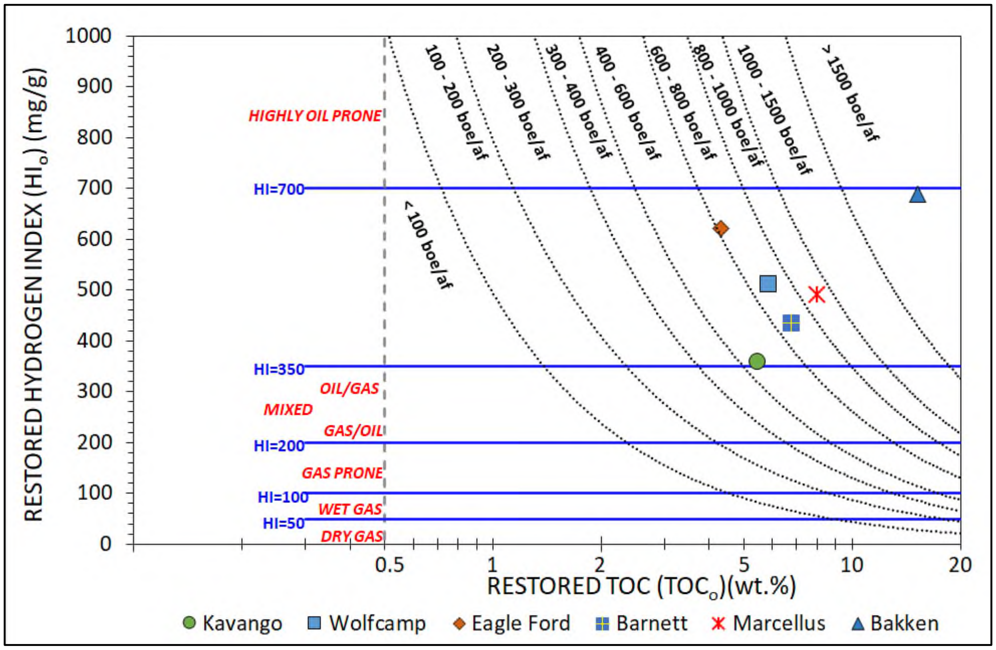


Figure 1. Comparison of average petroleum generation potentials from various known source rocks with the calculated 'conservative' value for the Kavango Basin. The conservative adjective is based on the lower HIo value for the Kavango Basin calculation. Note that the TOCo is similar to the Eagle Ford, but the HIo much lower.

Part 2. Conventional vs Unconventional Petroleum Exploration

The concern for onshore Namibia regarding unconventional is unfounded as clearly disclosed. When conventional reservoirs are compared to unconventional reservoirs, the former are easier and less costly to develop, recovery factors are upwards of 25x higher, and high energy stimulation is not required. In addition, more petroleum is expelled from good source rocks than retained favoring conventional production possibilities.

Unconventionals are not the first place to look to produce petroleum as they are the most difficult and least efficient reservoirs to develop. It would be nonsensical to go after such difficult and expensive to develop unconventional plays when there are much better conventional opportunities.

Part 3. Contamination

In Texas alone, 1,543,457 wells have been drilled; in Harris County where Houston is located, 13,407 wells have been drilled. People and the ecosystem are surviving very well. In Texas aquifers are generally in the first few hundred feet with the well bore cased and cemented to prevent contamination. The completed interval will most often be thousands of feet below such water reservoirs.

Of course, accidents have occurred, but nature is very good at reconstituting herself. The last thing any petroleum company wants is an accident of any kind. An environmental accident works against oil exploration, so no company wants that to occur.

Offshore California oil has been leaking out of the ground for millions of years. Even in some of California's vineyards, oil is produced within site from a well. Likewise, for the Paris Basin, the home of various wines and champagnes.

In fact, most contamination of water has often been a result of natural processes such as oil and gas seeps. Even the water faucets that were lit on fire in such movies as GasLand had gas reported by water well drillers prior to any petroleum drilling. One such case was proven to be a pre-existing condition in a court case against Range Resources in the Barnett Shale.

Part 4. Petroleum Possibilities Onshore Namibia

"Experts" have cited that there is no oil to be found onshore Namibia. Does anyone recall the same opinion for offshore Namibia? And going back further, around 35 non-commercial wells were drilled in the North Sea before the big reservoirs were discovered. One of the famous quotes from another oil company 'expert' was that he would 'drink all the oil found in the North Sea'.

The quoted expert from Harvard stated that the basin is too mature and would only have gas potential. While he may be an expert in his field, results from the Owambo and Kavango basin show that shallow source rocks are low maturity exactly the opposite of what the expert stated. Of course, if deeper, more mature source rocks are present, he states that gas is likely; does he not realize that gas is part of a petroleum system? It is also the best petroleum in terms of ease of production. In terms of consumption and economics it is cleaner than oil for combustion yet has valuable liquid components. If oil is exposed to high temperatures (>150ºC), it will eventually be cracked to gas. It is still productive as shown by the Marcellus Shale in the Appalachia basin, USA (about 2.0 – 3.0%Ro).

The so-called 'boiling off' of gas describes gas expulsion or escape from the source rock that can result in a conventional gas reservoir.

It is easy to understand why so many people question "experts" these days. We all understand the importance of the environment and petroleum, but we don't need to mislead on either.

Part 5. Drilling a Stratigraphic Test Well

Again so-called 'experts' have criticized the idea of drilling a stratigraphic test well rather than shooting seismic first and then drilling. The main citation in one article is from a non-geologist who is obviously voicing something she read, heard, or was told to say, i.e., asking why a stratigraphic test well was drilled before seismic.

When there is no geological or structural data available, drilling should start with a stratigraphic test. Such a well is the standard way to proceed in an unexplored area. Just for the record, the Alaska O&G Conservation Commission defines a stratigraphic test well as "a hole drilled for the sole purpose of gaining structural or stratigraphic information to aid in exploring for oil and gas". It is not intended as a potential production well. It is simply a well designed to obtain as much information as possible about the subsurface including taking high quality samples. Then, depending on what is learned and feasible, seismic may be initiated.

In the 1990s Shell drilled a stratigraphic test in the Turkana Basin, Kenya. The well revealed oil shows but Shell decided not to pursue. However, 20 years later an independent oil company has now produced oil.

The quote from the non-geologist, Shikongo, alluding to proceeding with a stratigraphic well before shooting seismic was "…like doing surgery without taking an x-ray". On the other hand, shooting very expensive seismic in an unknown, undrilled basin without stratigraphic testing is more like a doctor *perfoming surgery on a patient with full x-rays but on the wrong patient.*

Why people would criticize a stratigraphic test is beyond comprehension and in opposition to industry procedures. Below are numerous examples of stratigraphic test wells, which are an industry standard making both financial and scientific sense. As such, why would there even be a well designation called a stratigraphic test?

Example 1.

In the USA 24 deep stratigraphic test wells were drilled in the 1970s and 1980s in Alaska (14), Atlantic coastal basin (5), Gulf of Mexico (3) and Pacific coastal basin (2) (ref: OCS Report MMS 90-0028, May 1991). Among the goals cited for these wells was "to identify areas favorable for accumulation of hydrocarbons", to acquire "a basic knowledge of the geologic history", and various other data as described in the above referenced report.

Example 2. Offshore New England

"Ten wells were drilled on Georges Bank, offshore from New England, from 1976 through 1982 (table 1, figure 1). The first two wells were Continental Offshore Stratigraphic Test (COST) wells drilled during 1976 and 1977 by energy company consortiums to gain geologic information prior to offshore Federal petroleum exploration leasing."

Example 3. Colombia, South America

A press release by a Maurel & Prom dated February 2011:

"Colombia: Positive results of the first stratigraphic well in the CPO 17 license."

"A program to drilling stratigraphic wells has begun on the CPO 17 license in Colombia. This drilling campaign is targeting different geological objectives present in this license."

Example 4.

"The Harvey 1 well (Louisiana) was drilled in order to gather underground geological data. Figure 1 is a diagrammatic summary of the position, depth and subsurface geological formations encountered by the well."

Example 5. Onshore Indiana

Paper title: Deep test well in Lawrence County, Indiana: Drilling techniques and stratigraphic interpretations (1960)

Part 6. Sundry Misinformation in Rolling Stone article

a. Goodell's statement that 120 billion barrels of oil "... would produce 10 billion tons of CO_2..." omits a key fact – less than 1% of that total would ever be produced. There is no possibility of anyone ever recovering even 1% of the total petroleum generation potential in any basin anywhere in the world. Thus, his calculation on CO_2 emissions is 99%+ off. It is obvious from this statement that he and many of the other experts do not understand the total petroleum generation potential of source rocks despite having been provided, explained and documented.
b. To my knowledge there has not been a discovery; only oil and gas shows were reported.
c. The attack on the TSX Venture Exchange is short-sighted; it seems USA stock exchanges have provided their share of massive scams. Anyone remember Enron? Theranos?
d. Finally, the personal attacks are churlish, 5^{th} grader material.

Part 7. Pump and Dump

The personal attacks and references to 'pump and dump' reflect poorly on the individuals making such statements. Aside from being childish, such comments indicate little knowledge of petroleum exploration and the high cost of exploring especially in a rank wildcat area of a foreign country. It could be stated that any well that was funded and did not result in production would fit into such a scheme. Even the majors take on partners to reduce their financial risk. Independents are faced with the need to raise funds just as any other developer or entrepreneur. There is certainly a high degree of risk involved in petroleum exploration.

Part 8. Your Real Question

The principal question any investor would have is 'how likely will petroleum be discovered in the Kavango Basin?'. It is unknown, but still promising. There are a large number of unknowns in the basin, such as what is the extent of rifting and unconformities, which source rocks are present and have generated petroleum, are the promising targets charged and preserved with petroleum, as well as many other questions. However, the stratigraphic test has provided valuable data to further explore the basin.

The announced undertaking of a full petroleum system analysis, which will aid in determining the likelihood of petroleum charge in a given target. This will assist ranking of prospective targets in concert with the 2D seismic and eFTG results.

Appendix: Details of Computation of Total Petroleum Generation Potential

In order to compute the total petroleum generation potential, the original hydrogen content (or relative hydrogen content as indicated by Hydrogen Index (HI)), total organic carbon (TOC), and convertible organic carbon yields (as derived from pyrolysis S2 values) must be determined. Original values mean the values before thermal maturation of kerogen or organic matter has occurred. Thermal maturation (cooking per se) reduces the amount of TOC and HI as the carbon and hydrogen becomes part of the generated petroleum. The term transformation ratio (TR) is often used to indicate the amount of organic matter conversion, e.g., if a source rock was 50% converted, the TR would be 0.50 or 50% also.

From the presentation at the Petroleum Club a couple years ago, Permian source rocks from the Karoo Basin, South Africa were used as a starting point for estimating the petroleum potential of the Kavango Basin (see the figure from the Petroleum Club presentation). It is easy to identify the very high TOC values in the Karoo Basin even at this high thermal maturity (Ro ~2.5%) (see figure from presentation below). These TOC values were the basis for restoring the HI and then TOC and S2 to restored original values.

The conservative description of the total petroleum generation potential for the source rock is based on using a low original HI value: A value of 358 (mg/g) was used. A higher HIo would have meant even more petroleum. Published data from the Permian section suggests the possibility of mixed kerogen type, e.g., 50% gas prone (ca. 300 HIo) and 50% oil prone (ca. 600 HIo). This results in an average HIo of 450 or 38% convertibility similar to the Barnett Shale of the Fort Worth Basin, Texas. However, a HIo of 450 has more oil prone character than was warranted based on the mixed kerogen identified in the Karoo Basin. Therefore, the estimate for HIo was reduced to 358 mg/g as shown in the figure below. Those presenters or writers who have mocked 'conservative' do not understand the impact of HIo relative to source rock TOC as well as the big yields obtained from thickness and areal extent. A high HI has higher convertibility to petroleum, e.g., a HI of 800 has a convertible portion at about 67%; the remainder of the TOC is non-generative. At a HI of 200 only 17% is convertible to petroleum.

Note6: TOC is usually the focus of most source rock discussions. To understand the role of carbon versus hydrogen in petroleum generation, consider a diamond which is basically 100% carbon (presume it is organic carbon) with no hydrogen. What is its petroleum potential? 0.00. A TOC of 5% with a HIo of 500 would have far more potential than something containing 100% carbon.

The estimated original TOC is 5.44 wt.% and using a HIo of 358, the restored or original convertible kerogen is:

$$\text{Potential petroleum yield (S2)} = (\text{TOCo} - \text{TOCpd}) / 0.083 = 19.64 \text{ mg kerogen/g rock}$$

Note: 0.083 is the average organic carbon in petroleum itself although it can vary between 0.082-0.087.

The HIo value from this original S2 and TOC is calculated to be 361 mg/g TOC just slightly higher than the suggested value of 358 indicative of the need for a slightly higher value for the constant, i.e., 0.0837.

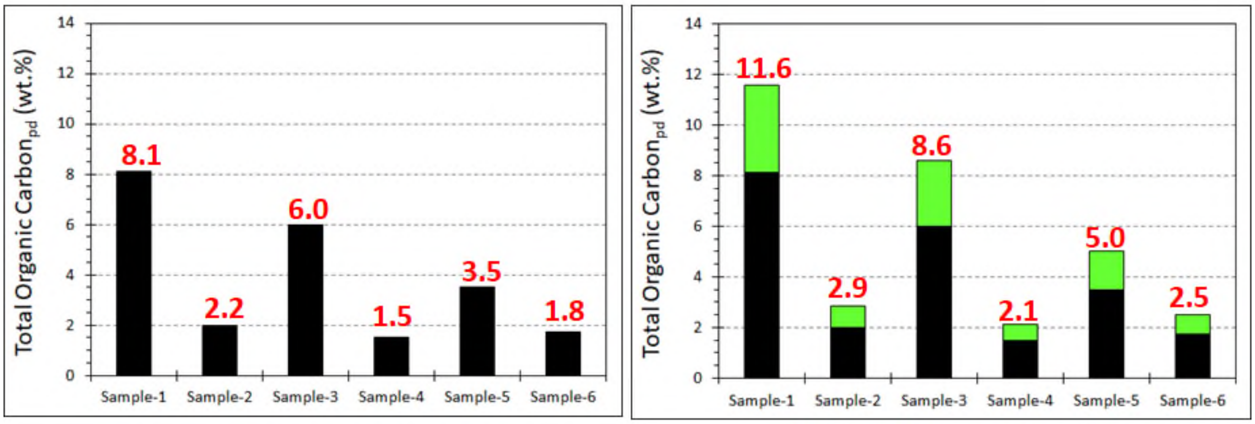
The conversion of this yield in mg/g rock to barrels of oil equivalent (i.e., oil and gas) requires a number of unit conversions as well as assumptions for the densities of produced petroleum and the rock matrix. For a petroleum density of 40^{o}API or higher a value of 0.085 g/cc is computed and the rock density is 2.7 g/cc for rock density (typical for carbonates).

19.64 x 23.4 = 460 boe/acre-ft at 0.085g/cc petroleum and 2.7 g/cc rock density

At only 100 ft of thickness, this computes to:

460 boe/af x 100 ft x 640 acres/mile^2 = 29.44 mmboe/mile^2/100 ft

Permian in Karoo Basin, South Africa



Average TOC at high conversion: **3.81%**

Utilizing a Hydrogen Index of 358 mg/g, Average restored TOC: **5.44%**

Difference in TOC is **1.63 %** or converted to petroleum **460 boe/af**

At only **100 ft** of source rock thickness, this is **29.5 mmboe/section**

The other three variables to input into the calculation are the (1) estimated TR (conversion related to thermal maturity), (2) estimated source rock thickness and, (3) the projected areal extent of the source rock.

A maturity for the source rock was assumed to range from peak oil (ca. 0.85%Ro) to early gas window (ca. 1.20%Ro) yielding TR values of 50% and 75%. If the Ro is higher, it means even higher amounts of petroleum, but likely more gas than oil.

For the source rock thickness, the thickness of the Permian in South Africa was used (443 ft) but also the estimated thickness from the Recon geological team.

The area of the lease block is 8.75 million acres. As such it was decided, rather subjectively, that only 12% of the total area would likely have a mature source rock or 1.05 million acres.

Estimated level of conversion: 50% to 75%

Estimated thickness: 328 ft to 400 ft.

Estimated areal extent: 1641 sections (mile2) or 1,050,240 acres (12%) out of 8.75 million acres

Results as shown previously:

66 billion boe to 99 billion boe TPGP

80 billion boe to 120 billion boe TPGP

Although the above explanation is my computation, a commercial software package named Kinex® offers a solution for industry use. Most of the major oil companies and geochemists use this software. As shown in the Petroleum Club presentation, the results are comparably large.

Lastly, the source both expels and retains petroleum with expulsion predominating at various points in the generation/expulsion cycle (a source rock will often generate and expel multiple times through its burial and thermal history). Expulsion predominates retention in the overall cycle. In addition, there are losses during migration and from poor seals. Thus, the amount of oil that is trapped and then recovered is only a very small percentage of the total petroleum generation from a source rock.