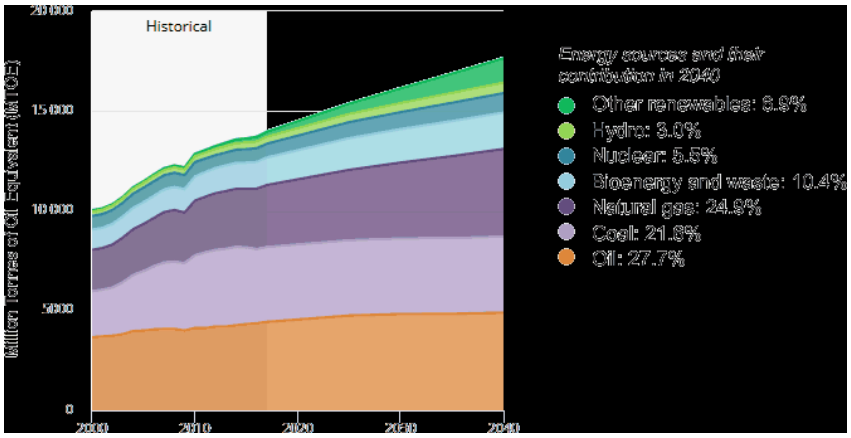
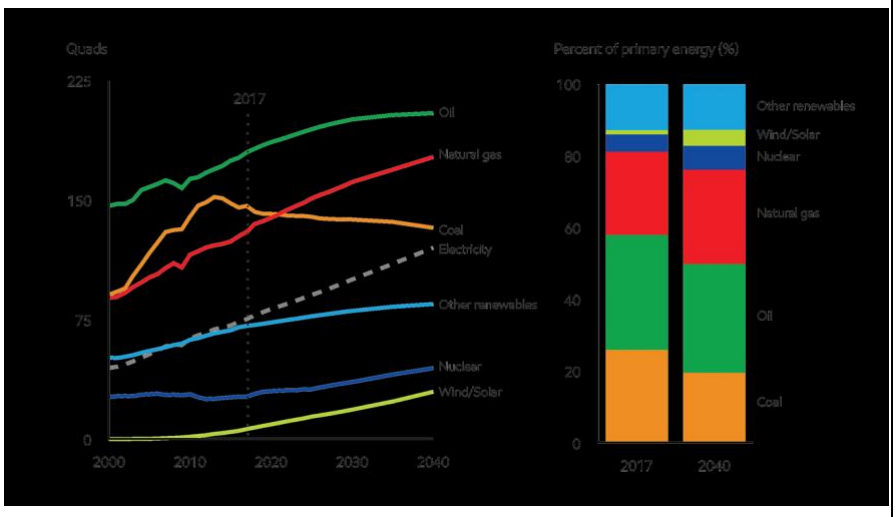
Julio Murillo	Great presentation. Question: Between the 5 different petroleum systems to evaluate within the Geological risk, in you experience, which one is the most difficult system to evaluate in terms of uncertainty and risk?	8
Jeff Aldrich	I believe you are asking about the 5 components of Risk Analysis in the **ROSE** methodology which are: 1) Source, 2) Timing\Migration, 3) Reservoir, 4) Closure, 5) Containment. I actually prefer to use the **WHITE** methodology of 1) Trap\Seal\Timing, 2) Reservoir\Porosity\Permeability\ 3) Source\Maturity\Migration, 4) Preservation\ HC Quality\Recovery. Whichever system you use it is most important that every team is trained and is consistent in using it. In either system the most difficult to correctly assess is the expulsion and migration of hydrocarbons. We have learned, through our work with unconventionals that our models of hydrocarbon expulsion efficiency that were laboratory generated in by Sluijk and Nedelof, 1984 and other after that are not correct. This is an area that needs much more research.	
Akinmuda Olusegun	What advice can you give upcoming geoscientist trying to build a career in reservoir characterization and modeling?	8
Jeff Aldrich	A model is designed and built to answer a set of questions. The biggest mistake I see is geo-modelers trying to "match geology" in that they are trying too hard to replicate every facet of the subsurface that is known. The first and most import point is to define what questions you want the model to answer, put some hard sideboards on the model. A model may be designed to understand ultimate recovery from the field as a whole, or it might be designed to understand well performance and design but those are two very different models. You would not use a basin model for oil generation and migration to design a 36 stage stimulation treatment. Both use different models designed to answer different questions. The software is a tool and there are leading softwares but software does change over a career – not one of the leading softwares existed when I started my career; expect rapid changes in software. Fundamentally understand both geology AND reservoir engineering. Modeling is done to understand fluid flow through the rocks. Get an understanding of flow units and try to see the reservoir as an engineer sees the reservoir so that you can assist the team in answering the questions. Finally, Rule # 3 – Visualize the reservoir in YOUR mind, think about it, turn it over in your mind until the model in the computer is working the way that YOU want it to.	
Mohammed Ghouse Mohiuddin	What do you think about Data Science and AI? Should petroleum engineers and geoscientsts peruse it or leave it to the computer people to do it for us?	7
Jeff Aldrich	The programing is a tool – not the endgame but just one of our tools. The best of the new geoscientists will be those that can code and understand data analytics. Computers can learn but they can not think; computer programmers can code but they don't understand geology and they can't visualize the subsurface based on limited data. Only a trained	

	geoscientist that code can use the tools of data analytics to pull information out of big data and decide if it makes any sense.	
Leeviya T S	As the non-renewable energy resources like gas and oil is being exhausted in the current scenario of explosive population, what do you think about the future of exploration and the relevance of technology in it?	6
	If you listen to most news media outlets you hear the phrase “peak demand” and think that they mean that we are at the end of the oil industry today. However, if you take a look at energy consumption forecasts by anyone that really studies the issue (the International Energy Agency- IEA, ExxonMobil’s annual forecast, BP’s annual forecast, the EU’s annual forecast, etc. they all have energy consumption AND hydrocarbon energy consumption increasing until at least 2040 if not until 2060. The diagrams below are the base case from the IEA and ExxonMobil’s latest forecast.   In both forecasts both oil and gas demand are increasing for the next 20 years despite the rapid growth in renewables. This is due to the large increase in total global demand and even a very large increase in	

	renewables will not fill the gap. This increasing need for hydrocarbon fuel cannot be met with our known base of reserves. Thus there is a future in both exploration and in development of oil and gas. There will be an increasing emphasis on gas resources due to their lower carbon footprint however oil resources will continued to be needed for transportation and petrochemicals for both your job lifetime and your children's. Every generation will have to learn new tools and new technology to stay on the "cutting edge" however the technology is just a tool that must be applied when you know how to ask the right questions and that knowledge is based on your understanding of geologic first principles.	
Norman Urrez	Which type of "Play" do you think might have been under-explored and could be volumetrically important in the near future?	5
	In the Q&A time I immediately thought of two types of plays, one a future frontier play of gas hydrates, known as clathrates, which have vast potential for low BTU clean burning methane gas but have a high degree of technological challenges and also potential environmental risks. Secondly our current horizontal drilling and completion technology is allowing us to go back into abandoned conventional fields that were left behind due to high water cuts, or low productivity and find ways to move from 20-30% oil recovery to 40-50% oil recovery; doubling the original field size. It is just like discovering a brand new field. I will also point out there are many basins undrilled (yes there are) and many, many more that are at an immature stage of exploration.	
Jason McClain	Does number 7 also tend too apply to unconventional fields and how the industry has managed these fields?	3
	#7 is that MOST FIELDS GROW THROUGH TIME SO DON'T SELL YOUR SELF SHORT. This is an excellent question for 2020 during a time that many companies are having to write down reserves, thus on the face of it the answer would appear to be NO. However, as an unconventional reserve auditor I will still argue the answer is yes. The issue today is that companies used an incorrect price deck and/or incorrect well type curves in forecasting production. The calculations on Original Oil in Place (OOIP) or Original Gas in Place (OGIP) are not being reduced but what is being affected is time frames for recovery and recovery factors under various pricing scenarios. We have learned and increased efficiency in well completions unbelievably over the last 10 years and the learning curve is not finished. The book of best practices in shale reservoirs has yet to be written. As an industry we have 3 generations of practice in conventional reservoirs to know what works and what does not. We now have 10 years in shale reservoirs and the Barnett Shale (the first one) is just now reaching steady state flow conditions where our equations of state will actually be meaningful.	

	Remember that the oil and gas in the ground never know that it has been "written off" from the books for economic reasons. If it was there volumetrically there in the first place then it is still there.	
Dr. Md. Farhaduzzaman	Very nice talk. But if I tell my nongeologist boss that All Maps are wrong, then he will be very angry and he will not allow me to drill any more in future. How can I pursue him positively?	3
	As I showed in the cartoon for number #6 on Uncertainty many managers simply want a single number or a yes or no answer. That makes their life easier and also easier to blame someone else if a well fails. It is incumbent on us to accurately discuss UNCERTAINTY in a manner that helps decision makers make decisions. There is uncertainty in everyday life: will it rain today, is the milk fresh or sour, how bad will traffic be (once we get back to actually driving to work!). Since we do not have 100% of all the information needed to accurately picture the subsurface [we will never reach this point] there will always be some amount of uncertainty. Our maps are our best interpretation and we should put 100% of our effort and pride into them. We must stand behind our work product and be willing to defend the work that we put into our maps, our cross-sections, our models. What I mean by "All Maps are Wrong" is a fundamental understanding that even though we put 100% of our effort into our maps we know that with additional data we MUST update our maps, improve our maps and change them. Our maps are but an imperfect interpretation of the sub-surface – though it may be the best interpretation – it can always be improved.	
Ken Williams	Isn't the EUR an economic number based on the time value of money. Production 20 years from now has very little present value, and is not included in the EUR, correct?	2
	This is a great question that shows the importance of the need for a fundamental understanding of economics, and yes, in many cases you are right, but not always. Estimated Ultimate Recovery (EUR) is correctly based on economics. The question is if in a time value of money analysis, normally shown as Net Present Value (NPV) if the production in 20 years' time has any economic value to a project. The answer to that depends on three primary factors: A) The amount of revenue the project is generating over time, B) The cost to produce that revenue over time and C) the cost of capital – known as the discount factor. The standard for years has been to use a 10% discount factor but due to the low interest rates many internal projects are today running at NPV3 or NPV5 instead of NPV10. If a project take a relatively low initial upfront capital but returns a large or a steady income stream then the value at 20 years can be relatively important. Many companies often want to understand the breakeven analysis, known as NPV(0) where no discount is applied. This goes back to understanding what the corporate targets are, how the company defines success. It is not right nor wrong for a company to be risk adverse or to	

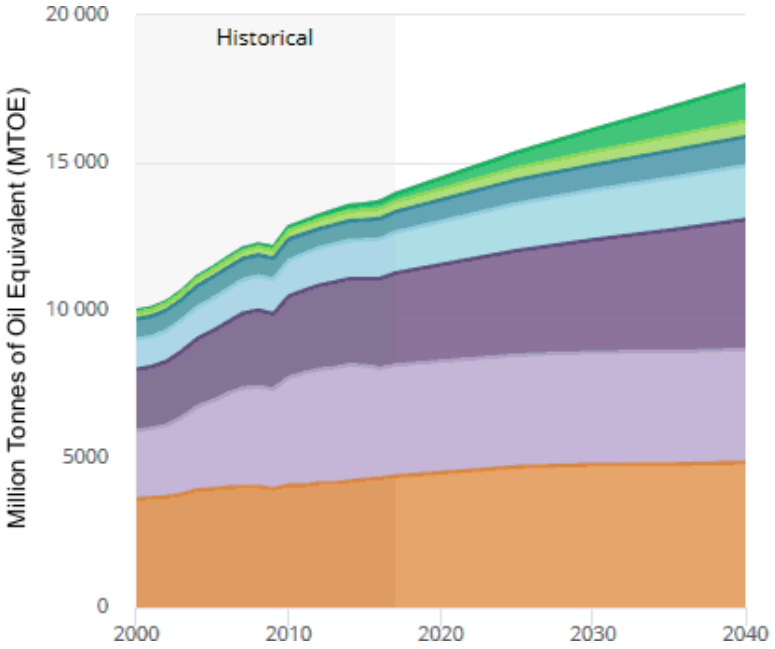
	tolerate risk but they must tailor their exploration plans to match their objectives. (see a question below) Today's geoscientist should have, as part of their basic tool kit, basic understanding of both statistics and business economics.	
Santiago Arango	Do you think that VoI (Value of Information) is undervalued nowadays because explorationists might be biased by their specific knowledge on one discipline, for example seismic?	2
	Most VoI exercises that I have seen turn out to be very subjective, placing a $$ value on purchasing digital well data, shooting 2D seismic, reprocessing, acquiring 3D seismic, inversion studies, remote sensing, etc. Specialists tend to place more weight, or value, on data or studies that they can use and discount other information. Thus it often ends up as a "Corporate Policy" as to what value to place on each type of information – a currency if you will – but 3D data may be much more valuable in an offshore delta amplitude play than remote sensing where in an onshore rift play remote sensing may be the most useful. I believe that it is important to be able to make a proper business case for the acquisition and deployment of any type of data through all phases of the business cycle. The cost of the information is to reduce the risk of a dry hole; to increase the chance of success. This can be modeled but it takes work and it requires a proper evaluation of prospect risk.	
Akinmuda Olusegun	What is the right approach to executing a project on prospect evaluation?	2
	1) Basin Analysis 2) Play Analysis 3) Understand what the Corporate Goals are and what the Minimum Economic Field Size is: Don't go hunting until you know what you need to hunt. 4) Gather your tools (data) and weapons (what methods do you need to find the prospects with the play(s) that you are going to be hunting in 5) Prospect Analysis There is so much more (I teach a 5 day class on this) but don't look for a prospect until you are prepared. One of the fundamental keys is #3, understand both what the corporate definition of success looks like and how much risk (# of dry wells) they are willing to tolerate. It is common for success to be different for different companies, do not expect success to look the same for ExxonMobil as for Cairn Energy. They can both explore in the same basin but be looking for different objectives.	
Pritish Mukherjee	A great talk touching very elemental cautions that old timers like us have learned by ourselves from scratch. Thanks Jeff for the content. How would you recommend a deep learning process on sets of subsurface	2

	data (which are primarily indirect records) to provide a satisfactory Machine Learnt Earth Model?	
	An excellent question on Machine Learning Methods (MLM). MLM are very useful to pull out correlations that we have not noticed from mountains of data. Beware – Correlation is not causation, just because there is a correlation does not mean anything other than a pretty graph. Once you have a correlation from the machine then your second part of work begins to query it to understand if it is useful and why it might exist. There any many papers (look to R. Roden or to M. Pyrcz) for outline steps on the process itself. **Solving exploration problems with machine learning** Deborah Sacrey, Rockey Roden Source: First Break, Volume 36, Issue 6, Jun 2018, p. 67 - 72 DOI: https://doi.org/10.3997/1365-2397.n0100 Smith, T. and Taner, M.T. [2010]. **Natural clusters in multi-attribute seismics found with self-organizing maps.** Extended Abstracts, Robinson-Treitel Spring Symposium by GSH/SEG, March 10–11, 2010, Houston, Tx Roden, R. and Chen, C. [2017]. **Interpretation of DHI Characteristics with machine learning.** First Break, 35, 55–63. **Rock Classification Based on Micro-CT Images using Machine Learning Techniques** Abdul Ravoof Shaik (ADNOC) | Ahmed Ahed Al-Ratrout (ADNOC) | Ali M AlSumaiti (ADNOC) | Abdul Khader Jilani (Datarobot) DOI https://doi.org/10.2118/197651-MSDocument IDSPE-197651-MS **Conditioning well data to rule-based lobe model by machine learning with a generative adversarial network** Honggeun Jo, Javier E Santos, Michael J Pyrcz July 14, 2020 https://doi.org/10.1177/0144598720937524	
william DeMis	Drawing uses a different part of the brain from looking at computer monitor. Please address this Brain involvement as part of the benefits of hand contouring.	1
	Hi Bill, Yes, When I am having difficulty "seeing" a reservoir the two best ways to visualize it are to 1) plot out a base map and hand contour it – erasing many time as I go – as the connection between the hand, the eye, and the brain to CREATE a form on a piece of paper, to shape by a set of contours a 3 dimensional object that you see in your brain makes you truly visualize it; and 2) when you are	

	stuck then draw a cross-section and prove (or disprove) to yourself the movements of the earth in that space. Once you do this it is so much easier to stand by your maps and to help others "see" the sub-surface. Computer algorithms can be used as a 'quick start' for a general form surface but I would never use them as a final map.	
Dr. Md. Farhaduzzaman	Could you please add some experiences on Deep Oil and Gas Resources ...	1
	I believe that you are asking about deeply buried targets and I have worked up and made a very large gas discovery below 23,000 feet and also worked on, at the time, the deepest onshore USA exploration well, the Danville Mountain #1. The current deepest commercial production is the Exxon Neftegas Z-44 Chayvo well in Russia with a total measured depth of over 49,000 feet and the completion at 40,604 feet (12,376 m). The field is expected to produce over 2.3 Billion barrels of oil. Deep structures are common, are often gaseous, but generally have low porosity and permeability. Our experience with unconventionals has shown us ways to produce low porosity and permeability reservoirs, however due to the high confining pressures these deep reservoirs may be difficult to stimulate; you must understand rock mechanics. As the Chayvo field shows oil can be reservoired at surprising deep depths and this can be anticipated if you understand the basin history. Technology led us into deeper water and geoscience also led with a greater understanding of turbidites and other deep marine facies. Technology led into ultra low permeability reservoirs and geoscience also led with an understanding of organic rock fabrics and depositional patterns and facies. Technology will lead into deeper drilling and geoscience will lead into better imaging and understanding of deep basin porosity and permeability systems.	
Meshari Alzahrani	Can we bit on a Lead (unknown petroleum system) but with a potential TRAP STRUCTURE ?	1
	Let's break this question down as it is asked. 1) We have an unknown petroleum system thus we are in a basin that could or could not be productive but we are working in a brand new unproven play and since Meshari says it is an unproven Petroleum System (not play) we are not sure that there is even a generating source rock. 2) There is a Potential Trap Structure which means that the trap elements are not confirmed. This may be due to insufficient seismic data to map the structure, or it is a stratigraphic trap and the pinch out is not clearly defined or the seal is not considered	

	adequate, or it is a fault trap and the fault is not defined well enough to know if it seals the trap 3) By the nature of the question I think the volume of the lead is interesting to warrant the consideration of drilling to ask if it is worth consideration. A volumetrically large structure in an unproven play in an unproven petroleum system with a closing element missing is a lead. It can be quantified under the PRMS but it warrants more work. That said, I recently completed an analysis for a client with exactly the same situation except that the petroleum system was proven. The cost of seismic exceeded a well cost and time delay was twice that of a well. Thus, the operator decided to drill the well to hold the lease. At the end of the day this is a business decision.	
Pritish Mukherjee	Thanks Jeff for a very interesting talk touching upon the basic elements in science which we old timers have learnt with trials and errors using the mind. With the present wave of AI & ML how do you think a deep learning process can provide a reliable earth model using the sets of subsurface data that is often indirect captures and processed.	1
	MLM must be trained on a dataset of known facts. Even cluster analysis (neural networks) or unsupervised networks must be then checked against reality before being allowed to predict on new sets of data. Thus, the first step of the geoscientist is to prepare the dataset, often from various data and the QC it. Secondly the geoscientist must evaluate the results of the MLM to see if it is correct, does it make sense (it often does not) and to correct the algorithms. It is an iterative process. My son works for the worlds largest supplier of MLM algorithms (EPAM) and they want the clients to work back and forth to improve the algorithms but they find the biggest failure is the lack of the iterative process. Computers can learn but they can't think.	
Viswanath Nandipati	When the subsurface maps evolve over a time and changes themselves in shapes areally and as well as vertically... The question I would like ask is how do we minimise the uncertainty in each of the parameters that change the dimensions of the reservoirs?	1
	There is a different workflow in exploration (trying to find something that has never been found before) and development (trying to optimize the exploitation of something that has already been found). The first has a risk of discovery so the primary goal is to reduce that risk more than reducing the volumetric risk, although that is important. In development there is no risk of discovery so volumetric uncertainty is paramount. When you do an uncertainty analysis in prospect analysis for exploration in most cases the area uncertainty is controlling factor for the volumetric uncertainty with either thickness and\or porosity being second. If there is 3D seismic coverage then often the geophysicist will have a very tightly controlled map and claim limited	

	uncertainty (there is always more uncertainty than they say – and I am speaking as a geophysicist) but there is uncertainty in the fill % of the reservoir. During the development phase the area of the reservoir and the contacts should have already been fairly well established so the biggest uncertainties are often in heterogeneities within the reservoir, saturations, and recovery factors It is always important to understand what are the largest uncertainties that you have at every point in time and then design your science program to reduce those specific uncertainties.	
Alimi Sodiq Abiodun	Thanks for the well delivered talk Dr, is GIS and Remote Sensing still relevant in the oil and gas exploration? Thanks!	0
	Absolutely! Mapping is one area that will have more and more machine learning applications, or automation for the routine tasks but the applications to use the data in an exploration sense, or to call up specific layers to assist in field development will be up to the individual. Remote Sensing will continue to evolve as the world tries different methods to monitor climate change; expect to see new tools be developed. There will be new technologies for both marine and non-marine applications.	
John Kaldi	Have you had a chance to use PRMS (or variation) to determine subsurface resource potential of pore space for CCS projects?	0
	Hi John, Another excellent question! Personally, I have not. My understand is that my colleagues at Sproule are working on a few projects that include CCS, one under PRMS (Texas) , one under COGEH (Alberta) and one, I believe under UNFC (Europe?). We have done lots of gas storage work but CCS is quite a different animal.	



Energy sources and their contribution in 2040

- Other renewables: 6.9%
- Hydro: 3.0%
- Nuclear: 5.5%
- Bioenergy and waste: 10.4%
- Natural gas: 24.9%
- Coal: 21.6%
- Oil: 27.7%