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The Future of Energy and Geoscience Careers*

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Introduction and Acknowledgements

On behalf of the AAPG's Division of Professional Affairs, I am pleased to present this paper devoted to "The Future of Energy and Geoscience Careers". I would like to thank my many colleagues at Royal Dutch Shell for their contributions to the materials that you will see in my presentation. This presentation will be a high level overview of what the upcoming decades may hold for our industry with a special emphasis on what this may mean for the careers of the geoscientists who will make up our organization. Describing the future is necessarily a hazardous endeavor. Accordingly, I will not try to prove any given scenario or set of forecasts. Instead, I will focus on some key themes, which appear to have a strong consensus, and which current trends seem to support as being more likely than not. I will also point out some areas where there is divergence among experts, and how this may impact the careers of geoscientists. In doing the research for this talk I have used multiple sources, including various government and international agencies such as the International Energy Agency (IEA), the current published Royal Dutch Shell scenarios, which my company has used for many years to help inform and guide its business strategies, and the future scenarios of some of the other leading IOC's, such as ExxonMobil's 2017 Outlook for Energy, BP's 2017 Energy Outlook and 2016 Statistical Review of World Energy, and publications from leading consultants such as McKinsey's 2017 Energy Insights. All of the data that I will show is in the public domain, or is a derivative of public domain data. The implications for geoscientists, however, are my own assertions and speculations, based on personal experience, informed by published literature, and conversations with leaders in our industry for whom I have great respect. I hope that this will provide a suitable backdrop for the presentations that will follow on more specific aspects of this topic.

The picture for the title slide (Figure 1) is from a favela, or low income sector, in the great city of Rio de Janiero, and is intended to reinforce the purpose that our industry, and we as petroleum geoscientists, have, which is to economically and responsibly find and develop the energy resources needed to power our world's economy, which enable many people to achieve higher standards of living.

Disclaimer and Cautionary Note

The material that I am showing contains scenarios that describe what could happen, but are not forecasts on what will happen, or should happen. Accordingly, I am obliged to share the following disclaimer notes with you, and advise you to not make investment decisions on the basis of my presentation today or the content shown.

The Energy Challenge

The achievements of our industry and our profession over the last 100 years are remarkable, but the challenges ahead are daunting. My company likes to refer to this as "The Energy Challenge". What underpins this view are some very powerful demographic and market forces that drive some hard but fundamental truths. The world's population is likely to grow from the current 7 billion people to 10 billion by the middle of the century. All will aspire to a higher standard of living. Most of us – 80% by my company's estimate – will live in cities by the middle of the century. Even with efficiency gains, this will require more energy – an estimated 60% more by the middle of the century, with 2 billion vehicles on the road (an increase of 250% from today). Renewables will increasingly capture market share, as this sector has been growing at an annual growth rate of ~15% for the past decade, and could triple by the middle of the century. But even with this rate of growth oil and gas will continue to dominate the world's energy supply during this time period. And despite the absence of complete international consensus on climate change, market forces are driving a gradual decarbonization of the global energy system, driven by increased use of natural gas, renewables, and improved energy efficiency.

Global Oil and Gas Resources, Production, and Market Share

Let me now turn to some numbers to illustrate these points and to underpin some important paradigms about the future. The first important paradigm is the emerging consensus that the world will not be constrained by resource scarcity. Last year the world consumed ~35 billion barrels of oil and ~120 trillion cubic feet of natural gas. Current and near term production are underpinned by very large quantities of oil and gas already in development and production. Longer term demand beyond the immediate future, however, will need to be met with Discovered Undeveloped and Yet to Find Exploration volumes. For oil these future resources are largely equally divided between conventional and unconventional sources, and are quite substantial. For gas, the story is a bit different, as Unconventional gas has progressively captured a larger portion of current production (in North America unconventional gas now comprises ~70% of current production). It also constitutes the largest single resource scope for the future, albeit recognizing a large fraction of this technically recoverable resource is economically challenged and may never be developed.

Forecasts of future demand are just as uncertain and fraught with as many assumptions as are resource estimates, and forecasts from different experts sometimes diverge. The impact of continuous compounding over many years can drive large differences in outcomes with only small changes in assumptions.

On the oil side, demand has grown over the past decade at an average annual rate of ~1%, about half the rate of total global energy demand. There is growing consensus that the rate of future growth will gradually slow, driven by efficiency and substitution in the transportation sector,

but when and by how much remains the subject of some debate. Future scenarios range between global oil demand out to 2040 continuing to grow at a rate much the like the recent past, to global oil demand potentially flattening sooner. Each incremental 0.1% of demand growth requires a new Permian Basin (currently ~2 million barrels per day) be developed by 2040. Regardless of which end of the spectrum turns out to be true, all forecasts point to oil volumes of roughly a trillion barrels or more needing to be brought to market to meet demand by the middle of the century. This roughly matches the trillion barrels of oil that have been consumed by the world over the past 35 years. But the rate at which future oil demand flattens will be very important in determining how much can be met with existing resources versus how much new oil and gas will need to be discovered, and how far down the cost of supply curve industry will have to go to meet global demand. This will be an important signpost for the future.

There is much more consensus on gas and its growing role in the energy mix. Over the last 10 years gas consumption has grown by more than 2% per year, which is slightly more than the 10 year annual average of total energy demand growth. Consensus forecasts show this growth rate remaining steady over the next 25 years, so that total global natural gas demand will be ~50% greater than today.

Bringing this together, there is growing consensus that the world is entering into a decades long Energy Transition, but that oil and gas will continue to dominate the energy mix for the foreseeable future, recognizing that while some viable substitutes are beginning to emerge, there are also some sectors such as petrochemicals for which no viable substitutes exist. It is expected that penetration of renewables into the market will start to erode the overall market share of fossil fuels by the middle of the century, roughly the working lives of AAPG's newest members. However, a smaller share of a much larger market will still require the efforts of all geoscientists to make this a reality.

The Key Role of Natural Gas

Given the relatively strong consensus for a growing role for natural gas in the energy mix, I'd like to drill down into more detail on the changes in this market, and what this may mean for geoscientists. As the cleanest-burning fossil fuel and a key source of supply for electricity generation gas will occupy an advantaged place in the overall energy mix. It is expected to double in overall consumption and overtake coal in market share by the middle of the century, driven mainly by a doubling of global LNG trade. In fact, global LNG volumes are expected to grow at a rate double that of overall gas demand. This represents the combined impacts of abundant supply, clear governmental policy preferences, and continued reductions in the cost for building gas-fired power generation and LNG export. In fact, LNG is expected to overtake long haul pipeline delivery as the leading means of getting product to market within this time horizon.

Gas consumption is likely to grow in all continents and in almost all countries. LNG is currently exported by around 20 countries and imported by around 30 countries, and these numbers are expected to reach as much as 25 and 50 respectively by mid next decade. The U.S., the Middle East, Australia, and Russia all are expected to grow as the leading exporting regions. Europe and the Asia Pacific region are expected to account for ~90% of global LNG imports. Commercial structures are also changing to meet the evolving needs of buyers, including flexible shorter-term and lower-volume contracts. The majority of the supply is expected to come from Unconventional resources, and with time will inevitably require relooking at plays or areas previously considered stranded or uneconomic.

Conventional Oil and Gas

Let me now move to a discussion of how these trends impact the types of projects in which AAPG members work. I'll start with conventional oil and gas, which is where I spent the formative years of my career. This will include Deepwater, arctic, and conventional onshore regions. These types of projects comprise the bulk of global production, particularly for oil, but span a wide range of positions in the overall cost of supply curve. This business has well established business models, and is truly a global enterprise. Importantly, it is geophysically driven, particularly Deepwater exploration and development. Increasingly these projects tend to be "long cycle" in nature, with a significant time lag that can span a decade or more between the investment decision and first cash flows. These types of projects, once initiated, are relatively inflexible and inelastic to market changes. The capital requirements to compete in this arena are very large, and accordingly, there are far fewer competitors than in the Unconventionals business. Scale and good risk management are critical to success to avoid "Gambler's Ruin" on a small or risky prospect inventory. Despite significant exploration investment over many decades, success continues to be mainly in well-established basins with prolific petroleum systems. Continued innovation in seismic imaging – the "eyeglasses" that enable geoscientists to see into the subsurface – allows these basins to continually reinvent themselves with new plays every few years, often when many are ready to write them off. However, a warning flag on the horizon is the overall industry discovery rate, which has steadily declined since 2010 and is increasingly comprised of gas. The rate of discovery of material Deepwater oil fields has been a fraction of global oil consumption for at least a decade, a trend that signals increased reliance on Unconventional Light Tight Oil to meet future demand.

Unconventional Oil and Gas

Let me move next to Unconventionals, where I have worked since 2009. This is a relatively new business, but one that has transformed our industry, particularly in North America, and particularly in gas. This is called "short cycle investment" because in contrast to large megaprojects, cash flows follow investment in very short order, and are largely within the same economic environment as when the investment is made. The investment is flexible and much more responsive to changes in the economic environment. Some economists have suggested that this will increasingly act as a shock absorber in the global market, and dampen future extreme market volatility, particularly removing exposure to future commodity price spikes. Only a decade ago tight formations constituted a tiny portion of U.S. production, but now comprises 45% of U.S. oil supply and 60% of U.S. gas supply. Since 2015 tight formations have sourced 70% of new oil supply and 80% of new gas supply that has come on-stream in the U.S.

Along the way there have been many skeptics of the commercial viability of this industry. Indeed, according to IHS, the shale industry has invested at a rate exceeding operational cash flows by ~30% since 2009. The industry was pioneered by independents who innovated in the field rather than the research lab. A broad range of capital sources financed this revolution, from new publically issued shares, to bank debt, to Private Equity. IOC's with more traditional capital sources are now also becoming major players in this game, and business models are maturing. Costs have steadily declined and reservoir performance has continually improved as we have learned how to target the best parts of the best plays, and to better drill and complete wells to unlock the most reserves. The best shale plays now compete roughly in the middle of the global cost of supply curve for oil, and at the low end of the cost of supply curve for gas. This business is still in its infancy, and the industry still has much to learn about how to optimize recovery and get the most value from these plays. But increasingly this business successfully competes for capital with conventional oil and gas even in low price environments.

The Unconventional story thus far has largely been restricted to North America. Despite very large shale resources around the globe, the lack of infrastructure and mature service industries, or unattractive fiscal terms, or sensitive environmental issues, or lack of local community support has caused a large scale withdrawal from international shale since 2012. Significant international production from Unconventionals in this decade will likely be limited to Russia, Argentina, Australia, and China. However, given the enormity of the prospective resource base and the need to meet growing future energy demands, I believe that this business will eventually expand outside North America, albeit slowly and in only selected areas that can satisfy the full spectrum of preconditions, both technical and nontechnical, for a successful Unconventional project.

Common Themes for the Geoscientist

I'd now like to turn to what this means for the practicing geoscientist. I have worked many years in both conventional and Unconventional oil and gas, and as these businesses mature I see increasing divergence in the career paths for professionals. Geoscientists in these respective businesses will develop different technical skills, likely live in different cities, and probably have different employment options.

But instead of concluding these two businesses present incompatible career options for the geoscientist, I'd like to point out that there are many more areas where these businesses are similar than where they are different. Deepwater exploration relies on the definition and maturation of the prospect. Unconventional exploration relies on the definition and maturation of the sweetspot. Both objectives require a multidisciplinary approach that is underpinned by a solid understanding of regional structure and stratigraphy, petroleum systems analysis, rock properties, geomechanics and/or geophysics, volumetrics, reservoir engineering, and economics. The goal at the end of the work flow for each is an investment that can attract capital. It has been my experience that it is too easy to see Unconventionals as simply a statistical "lawnmower play" that is largely driven by engineers whose only objective is to drive down costs. While cost performance is critical (just as it is in Deepwater), it is important to recognize that in any given Unconventional play about 50% of the revenues come from about 5% of the acreage. The difference between being in the sweetspot and out of the sweetspot can make or break an Unconventional venture, in the same way that the difference between a good prospect inventory and a mediocre prospect inventory can make or break a conventional venture.

To underscore this, the seismic line (Figure 2) in the slide from the Neuquén Basin in Argentina, one of the world's top emerging Unconventional plays, illustrates the complexity of the seismic stratigraphic framework in this basin. Finding the right parasequences in the Vaca Muerta with the right TOC, rock properties, fluid content, and geomechanics is crucial in this play to delivering commercial EUR's. Not all of the parts of the basin, or stratigraphic layers work economically, and the key to success is unravelling the subsurface to be able to get the right acreage and drill and complete the right landing zones in the right way to deliver the best wells. In this sense the fundamentals of good integrated geoscience and Play Based Exploration are, and always will be, foundational for any geoscientist, regardless of where he or she may work.

Finally, it is has also been my experience that it is the geoscientist who unravels the puzzle, who "connects the dots" to see the data that does not fit conventional wisdom, and who envisions the opportunity in his or her mind that others may not see. I truly believe that this is where our profession creates the most value, over and above bringing simple technical competence to a project. The classic statement by AAPG Founding Member Wallace Pratt that "oil is first found in the minds of explorers" applies now more than ever, and in all parts of our industry,

conventional and Unconventional alike. For future geoscientists, however, “connecting the dots” will mean not just technical integration, but also commercial integration. In a future that is increasingly dominated by gas, finding the market will be just as important as finding the resource.

Demographics

None of these future scenarios will come to pass without people – skilled, motivated, and dedicated to their mission. But the “Great Crew Change” that has been written about for so many years is probably coming to an end, as this latest downturn has resulted in the retirement of many of the remaining senior technical professionals in our industry. Many of those with whom I talk are happily retired, and there is no certainty that when the next upcycle starts their experience and skills will be available. Increasingly, the future will be in the hands of the next generation of professionals, particularly those so-called Millennials, that large demographic wave born between 1980 and 1995.

By the end of this decade, they will occupy ~50% of the total U.S. workforce, and probably a larger percentage of our profession. In many ways it is a truly remarkable generation – well educated, socially concerned, and incredibly adept at using information technology and social media. If Facebook were a country it would be the world’s most populous. Their expectations for their careers may differ from the generations that were born prior to 1980. According to the consulting firm, Global Collaborations, Inc., 45% of Millennials will choose workplace flexibility over pay, 72% want a job that has an impact, and 70% say that giving back and social impact are their highest priorities. They are impatient with bureaucracy and desire responsibility.

This leads to some interesting speculation on the impact of this generational change on our profession. The kinds of employment relationships that value flexibility (if taken to an extreme, the “uberization” of the oil patch) and providing a chance to have immediate impact suggest more flexible employment relationships and potentially more location variety to allow people to balance their professional and personal lives, all supported by ever stronger information technology platforms to enable work in virtual teams. All of this would need to be supported by ever stronger online continuing education platforms to enable professionals to continue to remain competitive in their specialties. This is a potentially exciting future, but one that I believe is not fully thought out as most companies have been in a “war for survival” during this downturn, and may not be prepared for the “war for talent” that may accompany the next upturn.

Slide 10: Concluding Remarks

It has been said that Exploration is “looking for buried treasure with other people’s money”. I chose the picture of the rainbow next to a Deepwater platform for my concluding slide because I hope that most geoscientists will eventually find their pot of gold at some time and in some place in their careers.

There are many important themes that have emerged from the latest industry downturn, which followed a decade long commodity “super-cycle” driven by paradigms of resource scarcity and market expectations for higher oil and gas prices over the long term. In doing the research for this talk I was quite surprised to find how much consensus there is on some fundamental new paradigms that will guide our industry going forward.

The first is the view that we are in the early part of a decades long “Energy Transition” that is driven by market forces as much as politics and will gradually lead to greater market share for renewables and gas and lower overall carbon intensity of the energy system. To quote Statoil CEO Eldar Satre from the recent CERAWeek conference: “The low carbon future will reshape the energy landscape.”

However, this transition will be long, and the size and continued growth of global energy demand will mean that oil and gas will continue to be the dominant forms of energy for the foreseeable future. If one looks at the amount of oil and gas that will need to be discovered, developed, and brought to market to meet this demand it truly constitutes a daunting challenge for our industry. To be clear, there is no consensus on the rate at which oil demand will flatten and possibly peak, but there is strong consensus that gas will play an ever increasing role in the global energy system, and that global movement of gas via LNG will overtake pipeline delivery, with significant consequences for development of the necessary feedstock resources.

Unlike the prior decade, the growing impact of Unconventionals and their increasing competitiveness on the cost of supply curve will mean that investors and companies will have greater choice on which resources to develop, and at what pace. This means that the job of the geoscientist will be to not only find and develop new oil and gas, but to find and develop oil and gas that can compete for capital in a world of increasing choice. Only those resources that can compete on a cost of supply basis will get developed, and low quality or high cost resources will likely remain stranded.

The increased market share of Unconventional oil and gas, with short times from investment to cash flow and great flexibility and elasticity to market forces, may, at least according to some economists, serve to dampen future market volatility.

I believe that the growth of Unconventionals will cause increasing divergence in career paths for geoscientists, but also provide them with more choices than in prior generations. However, fundamentals will remain as important as ever, regardless of whether a geoscientist works in the Permian Basin or Deepwater Brazil.

Finally, we are nearing the end of the so-called “Great Crew Change”. The next generation of geoscientists will increasingly lead this industry, and the continued development of information technology and social media and differing expectations and career goals may lead to business structures and employment models that may differ from those of my generation and earlier generations.

For those of you who are just starting your careers, the next decades promise to be challenging, exciting, and rewarding. I am confident that there will be good times as well as tough times. I wish you well, because the world’s energy system is depending on you to deliver. Thank you for your time.

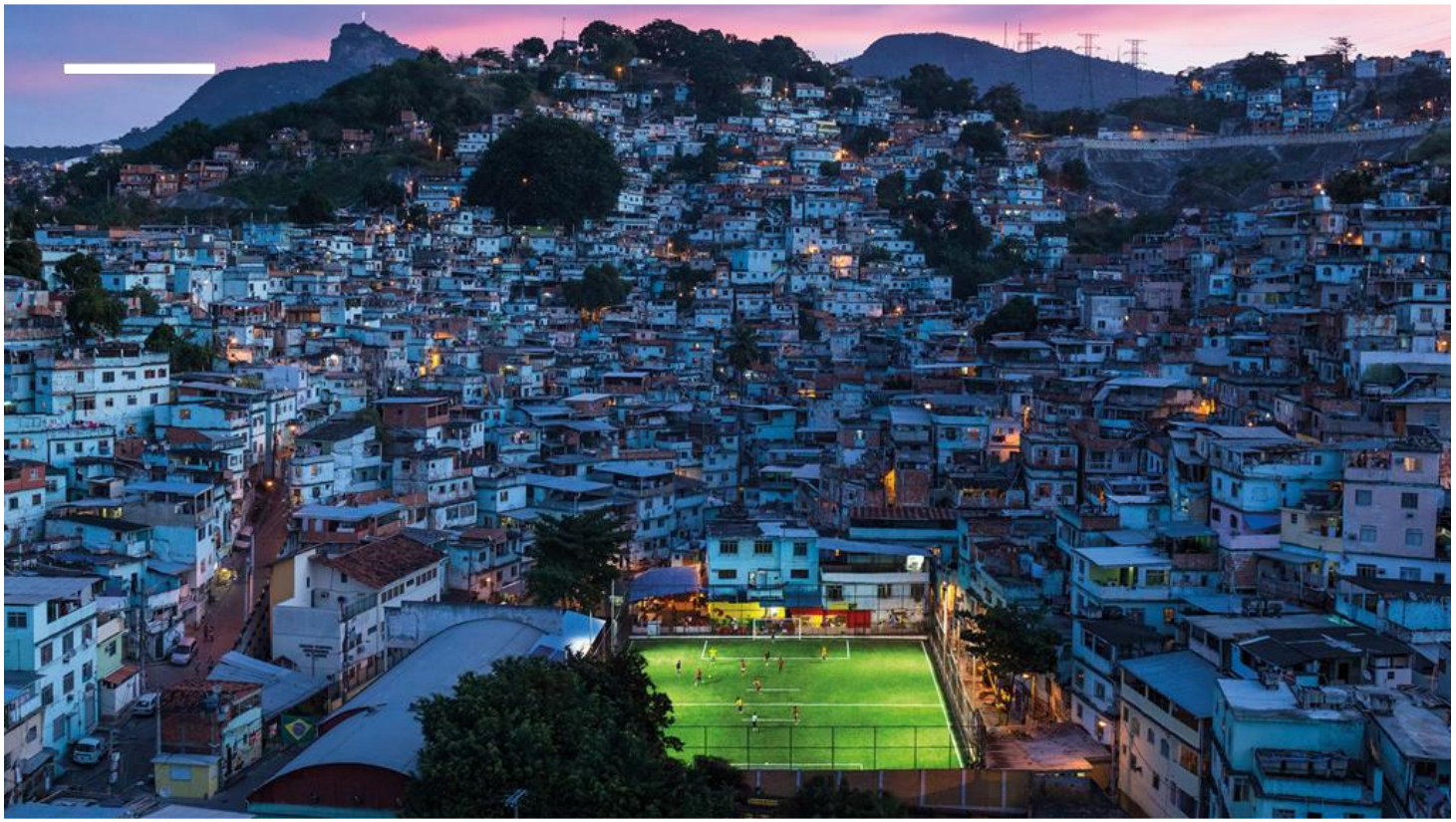

Figure 1. Favela in Rio de Janiero.

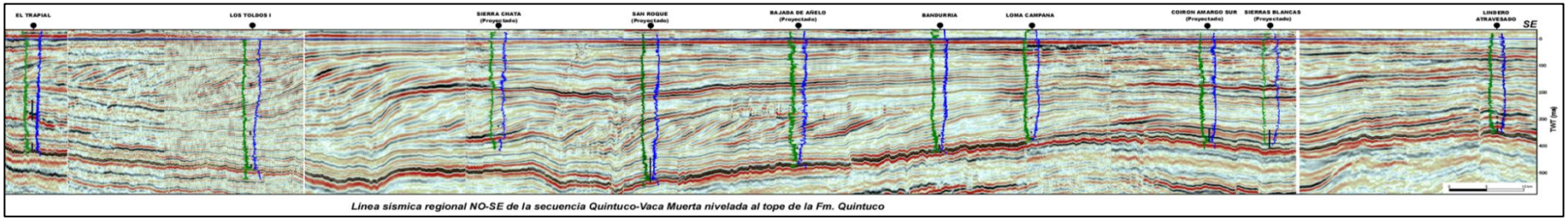

Figure 2. Seismic line Neuquén Basin, Argentina.