DRILLING & EXPLORATION WORLD

DEW

THE COMPLETE ENERGY JOURNAL

IN PUBLICATION SINCE 1989

INTERNATIONAL EDITION

Volume 32 Number 09

ISSN - 0971 - 7242

dewjournal.com

JULY 2023

"PETROPHYSICS The art of SEEING the UNSEEN"

Dr. Luis Fernando Quintero, a globally renowned oil & gas production management expert at Halliburton, listens to the wells to improve field production and reserves

HALLIBURTON - A PETROPHYSICS PIONEER

HALLIBURTON

Industry's 'closest to bit', ultra-deep boundary mapping helps operators unlock reservoir potential

Halliburton Introduces Earthstar® X Resistivity Service

Halliburton Company on June 6, 2023 introduced the EarthStar® X near-bit shallow and ultra-deep resistivity service, part of the iStar® intelligent drilling and logging platform.

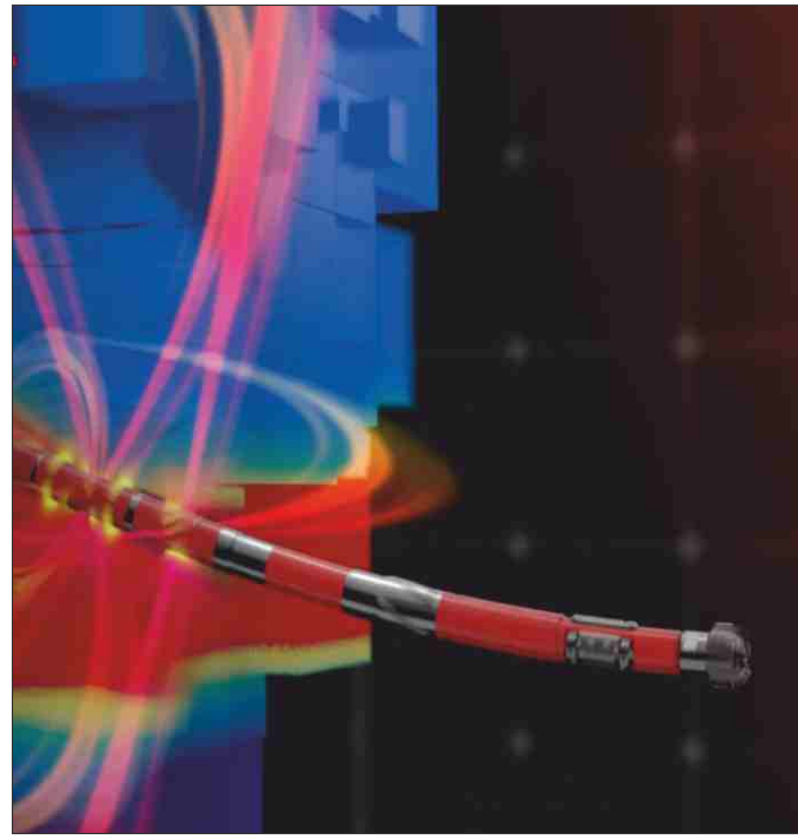
The EarthStar X service's near-bit, ultra-deep reservoir mapping sensor increases well placement accuracy - detecting geological changes early and enabling quick well trajectory correction to remain in the most productive zones and maximize asset value. Integrated shallow resistivity measurements allow early reserves evaluation and accurate fluid characterization to further improve reservoir insight while lowering operational complexity and risks.

"We listened and responded to operators to create the industry's 'closest to bit' ultra-deep resistivity measurements," said Jim Collins, vice president, Sperry Drilling. "The EarthStar X service enables accurate reserves evaluation to help place wells in the productive zone of even the most complex reservoirs."

The EarthStar X service accurately maps the geology in three dimensions using ultra-deep azimuthal resistivity measurements and inversion processing to geosteer, geostop, and geomap. Real-time fluid and bed boundaries visualization can place the well in the reservoir's most productive zone and increase the section's net-to-gross value. The industry's closest ultra-deep azimuthal resistivity sensor to the bit can detect formation changes early and make timely well path adjustment to avoid early exits.

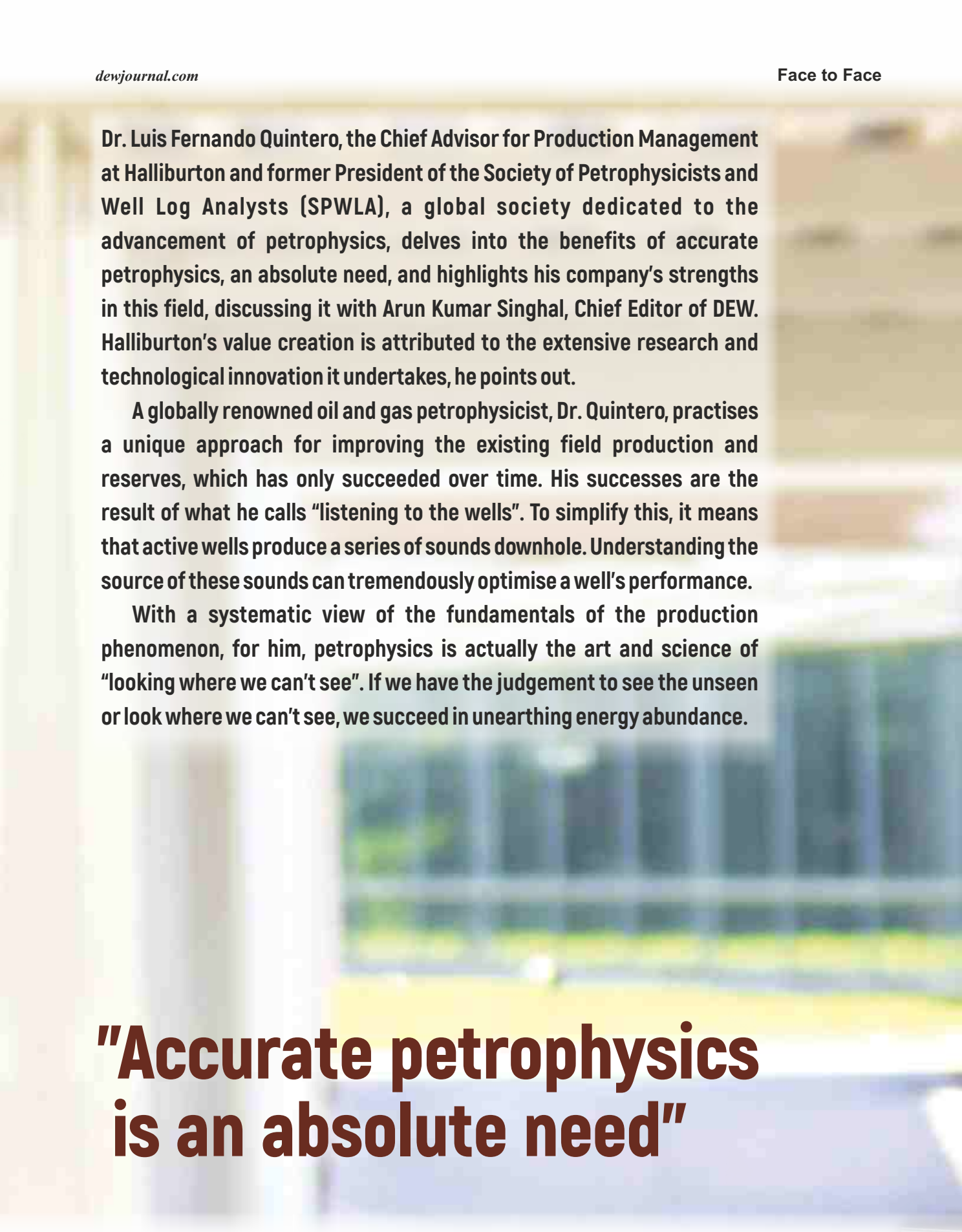
Unlock reservoir potential

The EarthStar X near-bit, shallow, and ultra-deep resistivity service unlocks reservoir potential with near-bit, ultra-deep boundary mapping. The early detection of geological changes enables quick well trajectory corrections to remain in the most productive zones of even the most complex reservoirs, maximizing asset value.



Proactive decisions with near-bit reservoir mapping

To geosteer, geostop, and geomap the geology accurately all around the wellbore the service uses ultra-deep azimuthal resistivity measurements and best-in-class inversion processing. Real-time visualization of numerous fluid and bed boundaries enables placing the well in the reservoir's most productive zone and increasing the section's net-to-gross value.



Dr. Luis Fernando Quintero, the Chief Advisor for Production Management at Halliburton and former President of the Society of Petrophysicists and Well Log Analysts (SPWLA), a global society dedicated to the advancement of petrophysics, delves into the benefits of accurate petrophysics, an absolute need, and highlights his company's strengths in this field, discussing it with Arun Kumar Singhal, Chief Editor of DEW. Halliburton's value creation is attributed to the extensive research and technological innovation it undertakes, he points out.

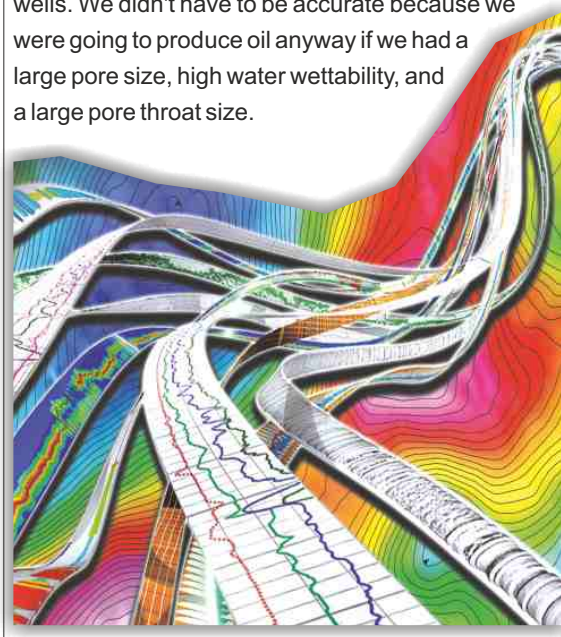
A globally renowned oil and gas petrophysicist, Dr. Quintero, practises a unique approach for improving the existing field production and reserves, which has only succeeded over time. His successes are the result of what he calls "listening to the wells". To simplify this, it means that active wells produce a series of sounds downhole. Understanding the source of these sounds can tremendously optimise a well's performance.

With a systematic view of the fundamentals of the production phenomenon, for him, petrophysics is actually the art and science of "looking where we can't see". If we have the judgement to see the unseen or look where we can't see, we succeed in unearthing energy abundance.

"Accurate petrophysics is an absolute need"

Dr. Quintero, you are an expert in petrophysics with a wide global experience. Even with the fast-evolving petrophysics, modern-day challenges still remain. What are some of the new-age challenges and how to over come them?

We need more accurate petrophysics. The reason for that is that previously, large pore throats, large pore sizes, large permeability, low viscosity, low wettability to oil or high wettability to water, and high-pressure environments were all very good conditions, so we could get by with less accurate petrophysics. In other words, any of these situations or a combination of them would lead to good production from oil and gas wells. We didn't have to be accurate because we were going to produce oil anyway if we had a large pore size, high water wettability, and a large pore throat size.



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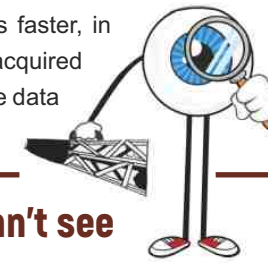
But now we don't have an abundance of those resources under those conditions. A 2%, 5%, or 10% error in the measurement now becomes very important. Before we could live with it, now we can't – we need more accurate petrophysics.

I understand the underlying reason for attempting faster petrophysics, which is to reduce delivery times and the associated costs. Our latest digital solutions can provide an infrastructure to get the data into the hands of geoscientists and petrophysicists faster, in some cases even as it is being acquired downhole, which is an area on the data acquisition workflow we can



Looking where we can't see

How Petrophysics helps overcome the physical impossibilities of seeing inside a faraway rock from a well borehole

Petrophysics is the art and science of looking where we can't see. Petrophysicists and log analysts interpret a large amount of soft data and very little hard data to estimate where, how, why, and how much energy can be available from a deep underground source. The only hard data we have prior to extraction is the one obtained during the drilling process, i.e., drilling parameters, cuttings, and responses obtained via logging while drilling (LWD). We use azimuthal sonic and ultrasonic services; pressure testing while drilling; far-away look-ahead resistivity; and other technologies during the brief time in the life of the well that the rock is virgin (almost). Immediately after that, we procure open-hole data from wireline logs and cores. But because the well can collapse, or we can have crossflow, or many other reasons, just when we need to validate the rock-fluid model, we cascade and cement the well. We can't see! And then we start the journey of figuring out what lies 1 metre, or 200 metres, away from the borehole. Seismic data, geologic modelling, gravimetry, and other soft data methods are validated (and can only be validated) near the borehole wall, where Petrophysicists operate.

It is here that petrophysics plays its part in seeing the unseen, even if we can't see because of the physical impossibilities of being inside a faraway rock, with the help of new technologies, improved algorithms, or interpretation methods that are state-of-the-art and help us see where we can't otherwise.

> Modern or new-age petrophysics provide hard data that allows resources to be properly classified as contingent, possible, probable, and ultimately, proved reserves.

focus on. The predominant factor should be the long-term value of the asset, not just the short-term economic gain.

Regarding the subject matter itself, where should we improve? In petrophysics, we only measure fundamental responses from the rock and from the fluid in the wellbore environment. We don't measure bulk properties as such. We measure an average property that we call bulk. If we have water saturation, for example, we don't measure water saturation; we measure the formation response where we inject it or pass an electromagnetic current, and we have the equivalent of a circuit, i.e., the equivalent of the formation resistivity. And we say this is resistive because it has a certain amount of oil and water. Then we put these readings into an equation, and from that, we say that only if the rock is of a certain type, and if the water is of this salinity, then the water saturation is calculated. But let's be clear, we don't measure water saturation. We measure how much voltage or current returns to a sensor. We measure a fundamental electromagnetic property.

The same thing happens with thermodynamics. We measure temperature, and from that value we calculate the heat capacitance of the rock, the fluids, or the combination of the two. We start deriving all the properties, including bulk properties and porosity, which is the amount of void space per unit volume. That's where we need to get better. We have to improve sensors, telemetry, and more importantly, get more representative equations. In doing this, the fundamental properties that we measure yield better and more accurate results for the key bulk properties.

We produce hydrocarbons from a rock that has a certain

Dr. Luis Fernando Quintero delivering keynote address on the topic "Looking where we can't see: How Petrophysics help meet the world's energy needs" during the 5th SPWLA India symposium during April 2023

The Chief Editor, DEW Journal, Arun Kumar Singhal, and Dr. Luis Fernando Quiintero discuss the emerging trends, technology, and solutions in the field of petrophysics.

Dr. Luis Fernando Quintero holds a BS in electronic engineering from Universidad Simón Bolívar, Venezuela, with an M.Sc., and a Ph.D. in petroleum engineering with a minor in geology from Louisiana State University.

He began his career in the oil industry in the oil fields of India in 1993–94 as a wireline logging engineer. Since then, he has worked as a petrophysicist, reservoir engineer, asset evaluation leader, production manager, financial analyst, and reserves auditor in Venezuela, India, the USA, Georgia, Azerbaijan, Russia, Ukraine, Greece, Indonesia, the UAE, Argentina, Colombia, and the UK. His involvement in HPHT wells throughout the world led him to be a key contributor to geothermal initiatives in Indonesia and Turkey, including well construction, diagnosis, and reservoir characterisation. Presently, he is the Chief Advisor, Production Management, at Halliburton.

Dr. Luis has been qualified to perform reserves reports and audit reports for private companies in the USA and for public companies traded on the Toronto Stock Exchange, the Australian Stock Exchange, and Petrosa in South Africa.

A SPE Distinguished Lecturer 2021-2022 and a SPWLA Distinguished Speaker 2020-2021 Dr. Luis also led SPWLA as its President during 2016–2017.

Widely travelled across the length and breath of the globe, Dr. Quintero has been a key-note speaker at countless conferences. With 14 patents and more than 35 technical publications, his writings on energy policy are notable.

Besides being an oilmn, Dr. Quintero is also "El Ingeniero" his artistic name (actor, songwriter, singer, video producer, film maker).

"When I think about petrophysics, I think about Leonardo da Vinci. Da Vinci if you look closely, Leonardo da Vinci's paintings always have this great balance between pure art and pure science. I think that petrophysics is precisely that: the pure art of understanding how fluid molecules interact with a rock."

thickness, a certain area, porosity, water saturation, oil saturation, mobility, and fluid. All of these are macro properties, and we can only measure micro responses from micro elements, which is an area where we need to improve.

The logical next step is that once we measure these micro-responses, how do we upscale them so we have a valid equivalent to a macro response? If the sequence of values is one, two, six, one, two, six, one, two, six, is the macro value the average, or should we give more weight to the larger values where fluid can flow? We also need to get better at the property upscaling because today, no upscaling property exists that is accepted by the industry.

Petrophysics being very delicate on which the success of the oil industry depends to a large extent, in such case is petrophysics an art or a science?

I see it as the perfect combination of art and science. When I think about petrophysics, I think about Leonardo da Vinci. Da Vinci is considered by many to be the greatest painter of his time, but he's also considered to be a genius engineer and scientist. He did fabulous work by illustrating his theories on flight and the perfect proportions of the body. If you look closely, Leonardo da Vinci's paintings always have this great balance between pure art and pure science. I think petrophysics is precisely that: the pure art of understanding how fluid molecules interact with a rock.

In new-age petrophysics, what does Halliburton have to offer?

Halliburton is a petrophysics pioneer. We offer better, more accurate sensors of those fundamental properties, better interpretation methods, real-time data transmission from the sensors downhole to the office, and excellence in execution.

For example, let's take the spectral energy window of nuclear responses to a pulsed-neutron generator. If we have a better definition of the window, then we can quantify the amount of carbon, silicon, aluminium, and oxygen near borehole region. This provides a better understanding of the rock because the rock is made of calcium, carbon, silicon, oxygen, and so forth.

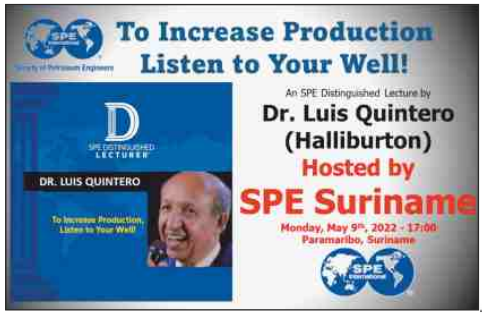
Now we make assumptions because we don't have a lithology measurement. At Halliburton, we can go into a library and predict the lithology from those pulsed-neutron responses. In the case of water saturation, what we have is a resistivity tool, an induction tool, or a dielectric tool.

At Halliburton, we provide our customers with better and more accurate measurements of those fundamental physical responses. Then, because we have a better response, it's easier for us to calibrate and determine the rock's bulk properties. We research, we innovate, and we patent our successes so we can deliver more value to our customers for their investment in our products and services. This is exactly what we state in our value proposition which is that "We collaborate and engineer solutions to maximize asset value for our customers".

Prestigious awards to Halliburton

Would you cite any case studies of recent times where this effort by Halliburton has been successful?

When we have more accurate sensors and more accurate workflows, our customers increase their overall production. We have several customer success stories and case studies posted on Halliburton.com.



To increase production, listen to your well !

Reading a book is great. Listening to a story is even better. A similar situation happens in a well. Active wells produce a series of sounds downhole. Understanding the source of these sounds helps tremendously in the optimisation of the well's performance, according to Dr. Quintero.

Production gaps are due to many causes, one of which is crossflow. The crossflow can be between pipes, past a sealing element, at the cement-formation interface, etc. Since leak flow is a dynamic phenomenon, it seems appropriate to obtain dynamic data to understand it. Fluids moving behind pipes create friction, turbulence, and sound. The well talks to us, and we should listen!

Optimisation of production rates with minimum intervention expenditures requires a reduction in the uncertainty associated with the diagnosis of the root causes of the production gap. If, as mentioned above, the cause is a leak, the effectiveness of a flood, for example, would rely heavily on the accurate diagnosis of such a leak.

A very comprehensive example of an injector well on an onshore mature oil field is shown to illustrate how listening to the well plus the integration of multiple dynamic and static downhole logs dramatically reduced the uncertainty of the location of the crossflow. Only a fraction of the water injected was helping to produce the oil, while the rest was accumulating (wasted) in a shallower zone. The economic impact of accurate leak detection cannot be emphasisedd enough. Fortunately, we listened to the well!

Tell us how new age petrophysics plays a key role in reserve estimation and ultimately in enhancing asset value.

The importance of petrophysics in reserves estimation can no longer be ignored. Under my tenure as president of SPWLA, the organization became an official member of the Oil and Gas Reserves Committee (OGRC). I was fortunate enough to be the first SPWLA member of the OGRC and lead the effort to write the Petrophysics chapter in the Application Guidelines of the Petroleum Resources Management System (PRMS). In that chapter, we addressed the key role of petrophysics in reserves estimation. Modern or new-age petrophysics provide hard data that allows resources to be properly classified as contingent, possible, probable, and ultimately, proved reserves.

You have earned the distinction of being a SPE and SPWLA Distinguished Lecturer. Share with us your experiences of reaching out to the industry, both from the SPE and SPWLA forums, as well as your major contribution as the president of SPWLA.

Knowledge sharing is one of my passions. Both SPE and SPWLA have chapters worldwide, so every time I give a lecture, I learn something from the attendees, their wells,

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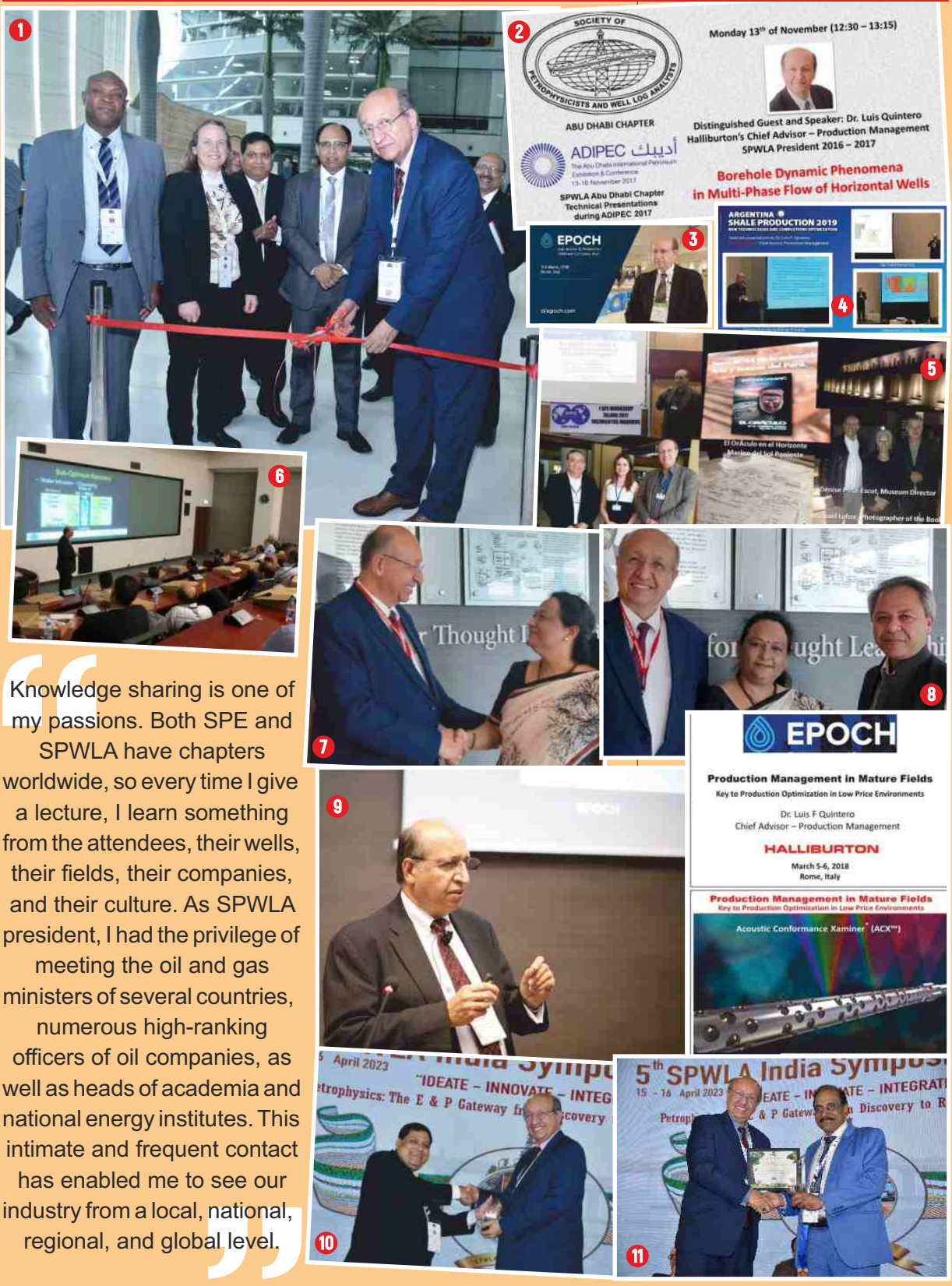
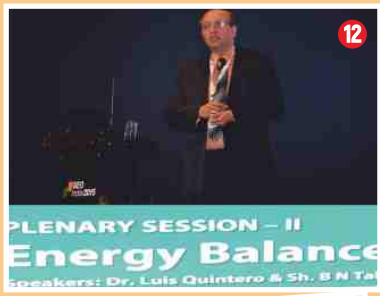
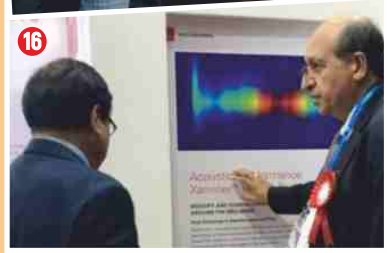
A glimpse of Dr. Luis F. Quintero at various global oil and gas events, delivering lectures, showcasing technology, and conducting training programmes under the banner of Halliburton, SPWLA, and SPE



"Knowledge sharing is one of my passions. Both SPE and SPWLA have chapters worldwide, so every time I give a lecture, I learn something from the attendees, their wells, their fields, their companies, and their culture. As SPWLA president, I had the privilege of meeting the oil and gas ministers of several countries, numerous high-ranking officers of oil companies, as well as heads of academia and national energy institutes. This intimate and frequent contact has enabled me to see our industry from a local, national, regional, and global level."





(1)In India Inaugurating the 5th SPWLA Symposium 2023 (2)ADIPEC, Abu Dhabi lecture (3)Lecture in Rome (4)Lecture in Argentina (5)SPE Lecture at Peru (6)SPWLA lecture at Saudi Arabia (7)With Director-Exploration, ONGC at OTC 2023, US (8)With Director - Exploration and the Executive Director, ONGC (9)Lecture on Mature Field in Rome (10 & 11)At 5th SPWLA Symposium, Mumbai (12)Lecture during GeoIndia 2015 (13)At Azerbaijan Academy (14)Lecture during OPTC London (15)Interacting with the then Indian Petroleum Minister during SPG-I conference 2017 (16)Interacting with former SPWLA India President and Chief Logging services during SPG-I conference 2017.

their fields, their companies, and their culture. I make friends who eventually become part of a large network of quality professionals and excellent individuals. We share the enthusiasm of contributing through our very special discipline to discover the mysteries of the subsurface, so that we can give the world abundant energy and create a better standard of living for mankind.

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You are often referred to in the oil industry as a "Production Management Maestro" for your innovative skills and interpretations to see the unknown in a reservoir or faraway rock. Share with us some of your path-breaking initiatives that helped the industry enhance subsurface insights.

Thanks for the compliment, but I would like to be considered someone that looks systematically at the fundamentals of the production phenomena. This approach, while simple in concept, is not exempt from potentially suboptimum shortcuts that influences past practices. My job is to avoid those shortcuts whenever possible. It's like a doctor searching for the underlying reason for an illness, instead of just treating individual symptoms. In that analogy, our wells and fields are our patients, so I encourage people to treat them as such.

The list of initiatives is quite long. However, recently I've been fortunate to work with great teams from several product lines within Halliburton in Colombia, Indonesia, the USA, Nigeria, and many other countries to increase the production rate and recovery factor of many wells and reservoirs. We achieved this by substantially decreasing or eliminating water and sand production and identifying asphaltene onset levels.

Dr. Quintero is said to be a great narrator who correlates incidences of daily life with complex issues of the industry in most of his lectures. How do you so simply simplify the complex?

I believe that this originated in my family, specifically with my parents. My father was a gynecologist, my mother was a psychologist who specialized in transactional analysis, and my first degree was in electronic engineering. Body, mind, and technology all under one roof. So, when we talked to each other about work, out of pure necessity, we had to use simple terms to get our

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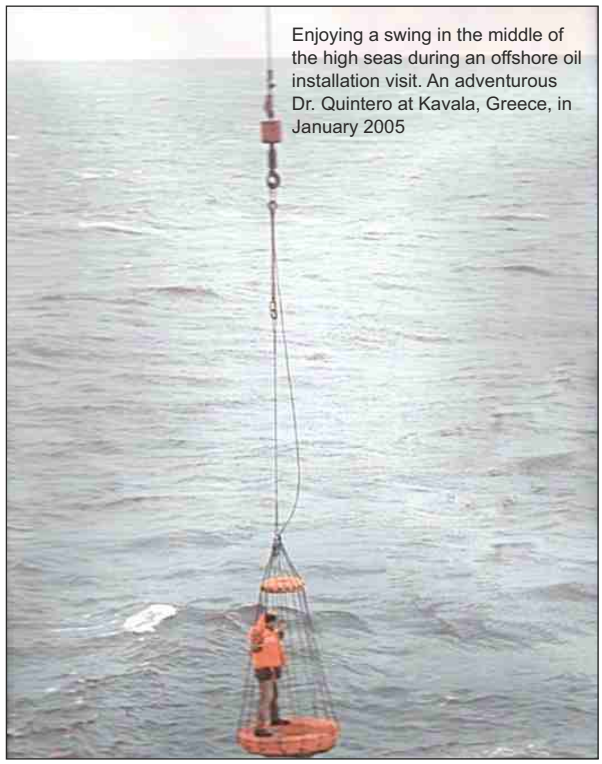

Enjoying a swing in the middle of the high seas during an offshore oil installation visit. An adventurous Dr. Quintero at Kavala, Greece, in January 2005

> My life in the oilfield has been filled with contrasting environments. I've worked in extremely high temperatures in fields in the Middle East, and in ultra-low temperatures in Eastern Europe. I've been in peaceful office environments, and in turbulent locations, and worked onshore and offshore around the world

message across. I quickly learned the immense value of analogies with them.

For example, the cause of a production gap may be better understood with a partial derivative of pressure versus radius, but the explanation needs to be given to the chief geologist, the asset manager, or even the company CEO. I don't think that a partial derivative will get the message across, but perhaps a visual example like getting stuck in traffic would do it. So, I use the traffic analogy while pointing to the equation.

Many see you as an inspirational leader, too. Tell us more about Dr. Luis Quintero and his inspirational skills that are interwoven with his technical expertise.

I believe that your attitude permeates into your job and your relationships. My life in the oilfield has been filled with contrasting environments. I've worked in extremely high temperatures in fields in the Middle East, and in ultra-low temperatures in Eastern Europe. I've been in peaceful office environments, and in turbulent locations, and I've worked onshore and offshore around the world. All this leads to opportunities to reflect on what is truly important; what are the must have's and good to have. In the end, I developed an enormous appreciation for the miracle of life and what our role is. I believe all of us are blessed one way or another and the only way forward is to inspire with positive thoughts and actions.

The Society of Petrophysicists and Well Log Analysts (SPWLA) is a professional society with a large base of student members. What would be your advice to the young petrophysicists?

Very few degrees in the world exist specifically for petrophysics. Students normally graduate either in physics, geology, or petroleum engineering. I studied electronic engineering. Students graduate from a scientific discipline related to the physics of the rock and then enter the realm of petrophysics.

My advice to upcoming students is this: the job of petrophysicists is extremely important for the benefit of every human being. This job has an immediate impact on how mankind lives. If we go into transition energies, like hydrogen storage, helium storage, or geothermal, we still need to drill wells. The same happens with carbon capture, which is not an energy itself but an energy mitigation. In all these developmental industries, we need to understand the properties of the rock and the fluid, how each affects the other, how it is affected by the drilling process, and how production affects the entire system. That's where petrophysicists play a key role. You cannot drill a well without knowing the physics of the rock, and that is extremely rewarding from a personal point of view. blindly

The cyclic nature of the oil industry may scare some. Part of our job in the Society of Petrophysicists and Well Log Analysts (SPWLA) is to take our message to students, industry workers, and also to the employers and investment community, because we will need to drill wells for a long time.

We cannot live without oil and gas for the foreseeable future. We owe our improved standard of living, in great measure, to our industry. At Halliburton, we also take a responsible and steady approach to support the energy mix transition.

Our industry has a positive impact in energy and in

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Azerbaijan Technical Newspaper: вышка, 24-30 April 2015

МЕЖДУНАРОДНОЕ СОТРУДНИЧЕСТВО РАСШИРЯЕТ ВОЗМОЖНОСТИ НАУЧНЫХ ПОИСКОВ И ДОСТИЖЕНИЙ

Презентацию провёл доктор Луис Ф. Кинтеро – главный советник SPWLA VP по технологиям (Halliburton). Луис Ф. Кинте-

вышка 7

Newspapaer reflecting Dr. Quintero's involvement with the Azerbaijan Academy of Oil and Gas

many different aspects of our everyday life. The capsules of health pills and the filters to prevent water contamination are made of petroleum-derived products. That's why the oil industry is going to continue to succeed, and that's where we're going to have our new generation of petrophysicists flourish.

What would be your advice for working professionals?

Continue to educate yourself and implement new technologies. Don't be afraid of revisiting prior assumptions because they got us here. I believe that with a level of uncertainty about the efficiency process, we can go back and rediscover many missed opportunities. It's better to revisit past practices, assumptions, and experiences and say, "We thought this was never going to produce, but with new technologies and methods, it will." We discovered and proved this in the shale revolution. We thought that horizontal wells would never be possible, but now everybody does them.

You have expertise in the reactivation of mature fields. What are the key essentials you advocate in this?

The key issue is to believe that the analysis, design, and operations that were followed several years ago in mature fields, were as good as they could have been, and can be improved with current experts, tools, sensors, and workflows. Once we look for improvement, the gaps will start popping up, but it is up to us to determine which are relevant and important and which can be left untouched.

Generating high-resolution images in oil-based mud to improve formation evaluation is important. Does Halliburton have a technology for this?

We need to understand the physics of the phenomenon that we want to analyze. Oil-based muds are a great aid for wellbore stability and enhance drilling performance. At the same time, the invasion profile and response to electric current is different than water-based muds, since water is conductive, and oil is not. Without going into deep electromagnetic theory, the concept of impedivity, which encompasses electric and dielectric response, is used in these situations. Halliburton's StrataXaminer™ is the most advanced tool for open hole imaging in oil-based muds. It emits three high frequencies, has the option of six or eight pads, and 24 electrodes per pad. With this tool we can have up to 100% borehole wall coverage (depending on the hole size). It is truly high tech at its best for borehole imaging.

As regards the issues related to water conformance

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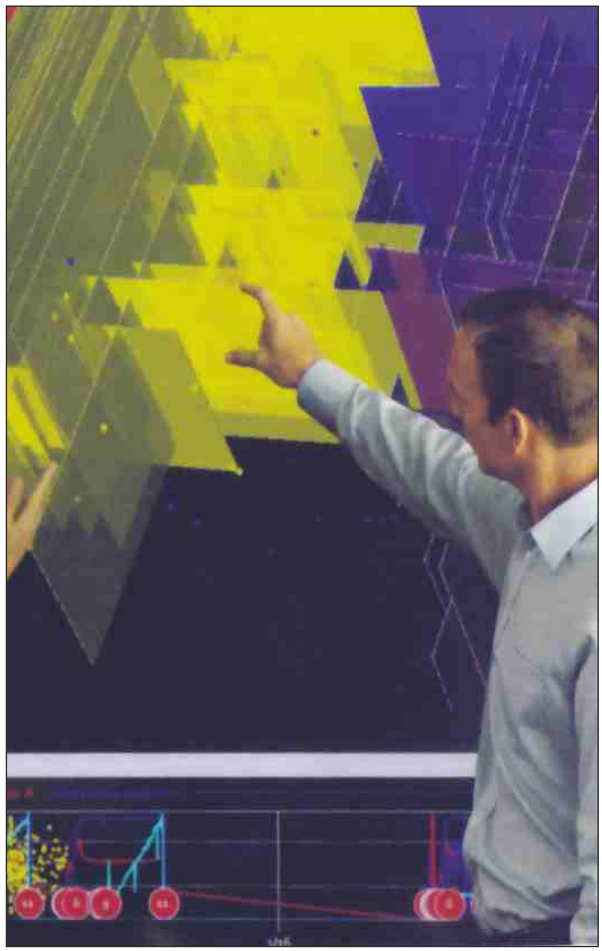
"When NMR logging was in its infancy, Halliburton took it to the field worldwide, while others claimed it was impossible. We have an early advantage that we have kept through continued research."



"Thinly bedded, high-contrast formations require non-standard core analysis procedures, and standard plug-based analyses need alternate technologies. The ultimate technology is the use of digital rocks with Halliburton's Integrated Rock Analysis Ingrain®"

and/or unwanted fluid production, Halliburton's conformance solutions have proven effective in vertical, highly deviated, and horizontal wellbores, including challenging completions. How?

At Halliburton, we have done extensive research in the use of polymers, mechanical shutoffs, and improved our permeability modifiers. The products H2Zero, Back-Stop, and WaterWeb come to mind. But the success comes only if the root cause diagnosis is accurate This can only be achieved with a proper understanding of the wellbore with solid data acquisition through state-of-the-art sensors.

Once the root cause is understood, then we enter the design phase. What can be done with the current condition of the well? Is an intervention in this well worth it? How about the commonality of the cause? This can lead to an overall production increase of several fold for the entire asset.

Will you shed light on how reservoirs with thin laminations can be more accurately evaluated?

Thinly laminated reservoirs are those where the thickness of the bed is smaller than the resolution of the tool. But remember that hydrocarbon production happens at pore level. So, the resolution of the tool needs pore level scale.

However, there are levels of homogeneity, which means the layers may be just slightly different. In such cases we ignore the small changes and have "thick homogeneous layers," where most tools and assumptions work fine. But when the properties of the layers are very different, like a sand-shale sequence or a highly heterogenous reservoir rock, then modelling of the layers is mandatory. Modelling can only be done when the data is representative of the phenomenon at pore level. The more precise logging data today in thinly bedded reservoirs is the response of the hydrogen protons that are in resonance with a magnetic source. Halliburton is a pioneer with our Xaminer® Magnetic Resonance (XMR™) technology for NMR logging in open hole. The XMR has strong signal to noise ratio and a great ability to resolve micropores.

At the same time, in logging while drilling, we also have our Magnetic Resonance Imaging Logging-While-Drilling Sensor (MRIL®-WD™). This tool gives us real-time measurement of porosity, total porosity, and microporosity while differentiating between bound and moveable fluids.

It's important to remember that when NMR logging was in its infancy, Halliburton took it to the field worldwide, while others claimed it was impossible. We have an early advantage that we have kept through continued research.

What new methodology can be employed to better characterise thin beds and maximise reservoir

potential in thinly bedded reservoirs?

Thinly bedded, high-contrast formations require non-standard core analysis procedures, and standard plug-based analyses need alternate technologies. The ultimate technology is the use of digital rocks with Halliburton's Integrated Rock Analysis Ingrain®. This digital rock is the best hard data, since it is a 3D representation of a rock using X-ray micro tomography (MicroCT), where we use a focused ion beam scanning electron microscopy (FIB-SEM). The rock is observed at pore level, and the heterogeneity is then upscaled via wireline logs to understand the production mechanism. This is ground-breaking technology, and because it's not a physical rock, but an exact replica, we can do many tests in a short amount of time, minimizing and optimizing the use of cores. Integrating digital and physical core analyses leads to reduced uncertainty, petrophysical properties, and accelerated decision-making based on advanced formation evaluation.

Digitization is now interwoven into all technologies and all aspects of the industry. How can AI and ML enhance and unlock value for the oil industry?

Digitization in the earlier days mainly meant moving from an analogue response to a digital response. That was cumbersome so we started acquiring data digitally. We acquire the data response at certain periods, and those become the digits of that data. As an example, if a parameter increases from zero to five, we measure 0, 0.01, 0.02, and 0.03 at equal intervals in time or at equal intervals in space. Based on that, we establish whether the increase is linear or not. Everything became digital after the recording.

We do the same thing with electric logs, whether it is logging while drilling, open hole, or cased hole. In the analogue days, we played with signals. Now we record digitally. Once the data is digital, we can work with the numbers to accomplish the best outcomes. We use digitization in for example, assisted and automated lithology interpretation, and in scalable earth models, optimizing lithology and fluid parameters.

Machine learning will take all that digital data and then apply the proper algorithms so that we get the response that we want. But it needs to learn. That's why it's called machine learning. Learning depends on the material, the student, and the teacher.

Let's recall the first part of the interview and assume that for some reservoirs, wells, or fields, we were less accurate in our data gathering, but we could live with it. A few times we were successful in our efforts, but we saw those times as outliers. The machine will not learn properly in this situation, because learning depends on the teacher and the material.

Artificial intelligence is a more advanced process where the machine itself applies algorithms and begins to understand and apply the principles that were taught. But we need to assign the proper weight into the different principles that we use to gather the desired data. For example, to determine whether I am fit or not, do I validate more my height, weight, the size of my belt, or the amount of calories that I eat?

All this data determines, eventually, the proper diet for a person. After all of this, someone says "Don't look at your waist size; look at the number of hours you are sleeping," and so on. So, someone needs to identify a weighing element and the weight proportions.

We might have a higher level of artificial intelligence that would say, "Don't worry, we have enough data points in the world to start predicting what should be done or start counselling or advising what should be done." The problem is every well and every rock is unique. Even in basins where we have 10,000 wells, only a portion were laterals, others were horizontals, some had dual completions, some had partial completions, some had a particular drilling fluid, some had a different drilling fluid, some may be in this horizon, some may be in different ones. When you start dividing into the ones that are equal, you maybe have only 20 that are comparing apples to apples. And within those 20, you have a large variation. So how much value would artificial intelligence add when you're overseeing those 20 wells? Maybe none, because 20 samples have limited statistical value. That's one of the challenges of artificial intelligence, which we are addressing, for example in digital twins.

The other challenge is that we start summarizing and averaging. Going back to the fitness example, we say, "You weigh less than you should, these are your proportions, or you weigh more than what someone at your height should. We put everyone in the same bracket, where they obviously don't belong.

We expect many missed opportunities because the missed opportunities are what we are after. That's what I stressed at the beginning of the conversation. We're looking for the small pore throat, the small pore size, and the large water saturation. Today we're looking for spaces that were not easy to find or produce previously, but we

> Halliburton is committed to increasing the production and recovery factors of the oil and gas fields of India. If I am fortunate enough to be involved, I would emphasize three key elements. First, to know in as much detail as possible the rate production history of the well and the field. This information should include the conditions of the wells. Just like in medicine, a good diagnosis relies heavily on the patient history. Second, initial reserves associated with the reservoir field and basin. It's important to know whether the "patient" has enough life left. Third, the conviction that yes, we can increase the performance. Without that conviction, every challenge is an obstacle, but with it, every challenge is an opportunity.

Dr. Quintero along with Indian and overseas E&P experts brain storming on solutions for accreting new reserve and maximising production from existing brown fields and new frontiers in complex and unconventional reservoirs with new ideas and innovation during the 5th SPWLA Symposium in Mumbai.

A throwback photo of Dr. Quintero with Indian oil industry personnel at Narsapur, India, in the year 1984.

have a large database of the ones that were easy to find. So artificial intelligence, again, may be biased towards the easy-to-find areas because that's where the majority of the wells are today.

The coming age doesn't allow us to go without ML or AI. So how do you manage these at Halliburton to your advantage?

At Halliburton, we are making steady progress in adapting and using ML and AI. At the same time, we have to lead consciously, step by step. We recognize that data exploitation, analytics, remote operation, and automation are critical elements that we actively incorporate as we transform and evolve the way we work to plan, design, execute, and maximize the optimal well.

You have previously worked in India. If India invites you as an expert in reservoir and production management, what are the three things you may like to emphasize for better results?

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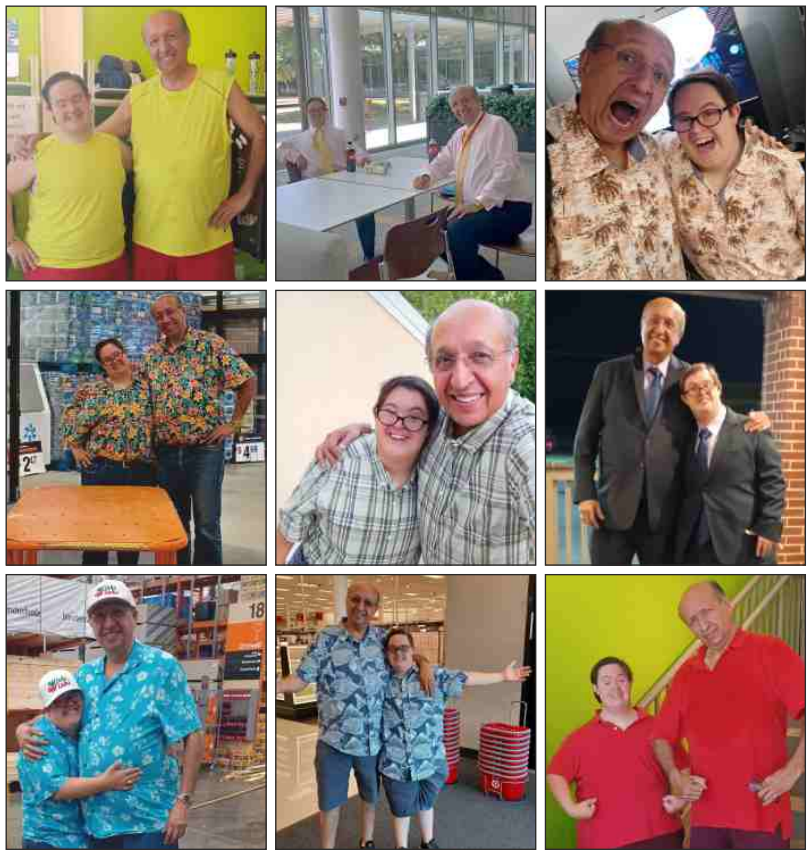
What is your assessment of how ASEAN countries and India can achieve further E&P success from discovery to recovery?

The industry, and Halliburton in particular, have the latest and safest technologies available, the fields have proven hydrocarbon systems, we have the best people, and a willingness to achieve better recoveries. I have no doubt that we will soon see an incredible jump in discovery success and production of existing fields.



Not just an oilman!

Dr. Luis wears different hats. Besides being an oilman of eminence, he is an actor, songwriter, composer, singer, musician, and video producer. His finest video songs are all available on various social media platforms. You will appreciate this side of Dr. Quintero's personality as well.

"Wishi Wishi" is one of his lovable video songs. And "Wishi Wishi" is also a movie, a comedy presently in the preproduction stage, where Dr. Luis is casting his son Pablo at the centre of things.

View a glimpse of the happy-go-merry multi talented Dr. Luis in his videos!

> On a personal note, I love spending time with my family and especially enjoying the simple things in life with my son Pablo. We do yard work, go to the gym, play in the pool, and, on special occasions, go to Halliburton's office together. One of those simple but fantastic pleasures is that we dress alike, from head to toe, every single day.

On the personal front, our readers would like to know Dr. Quintero's likes and dislikes both on personal and professional fronts and of his leisure hobbies.

With regards to my profession, I truly enjoy my work. I find pleasure in contributing to solve the myriad of issues that need attention, be it technical, administrative, or policy. I dislike not having enough time to remain in one place to get to know the people and the culture more.

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