

Finding Petroleum

8-9bn barrel recent discoveries in Mauritania and Senegal - equivalent to nearly two Forties fields

How Kosmos Energy operates

Impact Oil and Gas in Gabon

Why understanding crust is key to understanding geology

Accelerated interpretation of geology

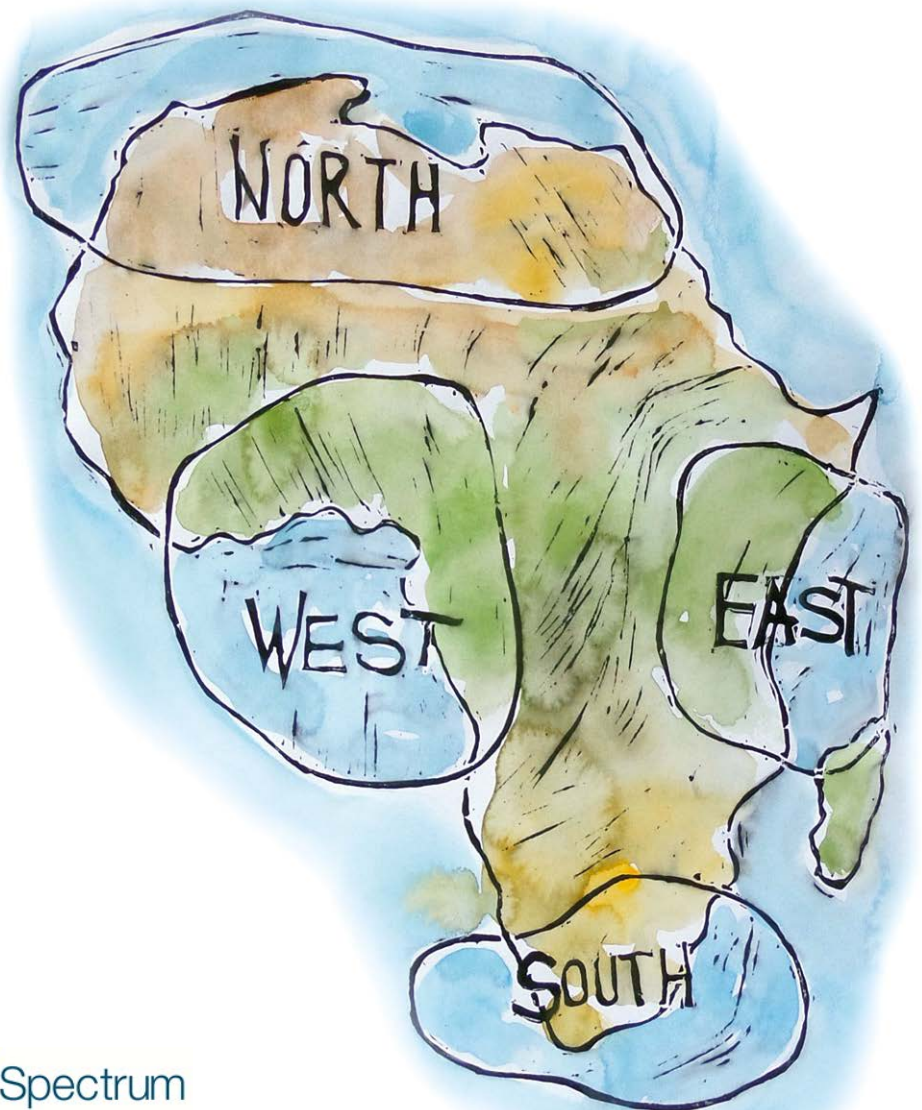
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Finding Oil & Gas in Sub Saharan Africa, London, Sep 19 2017

Special report

Finding Oil & Gas in Sub Saharan Africa

September 19 2017,
London



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Finding Oil and Gas in Sub Saharan Africa

Finding Petroleum held a forum in London in September 19 2017 looking at developments with finding oil and gas in sub Saharan Africa, with speakers from Kosmos Energy, Impact Oil and Gas, Spectrum, Lyme Bay Consulting and PGI. We heard that North West Africa is perhaps the most exciting place in the world for oil and gas exploration at the moment

North West Africa, particularly offshore Mauritania and Senegal, is probably one of the most exciting part of the planet for the oil and gas industry, with maybe 8-9 billion barrels of oil equivalent found in recent years, said Dr Neil Hodgson, executive president Europe and Middle East with seismic company Spectrum.

He was making opening remarks as chairman of the Finding Petroleum forum Finding oil and Gas in Sub Saharan Africa, in London on Sept 19, 2017.

To put that in perspective, the Forties field, one of the largest fields in the North Sea, has produced 5bn barrels to date. So it is like finding nearly two more Forties fields, by companies including Kosmos Energy and Cairn Energy.

And the discoveries so far are "just the start," he said. "The play trends that have been opened up by Cairn and Kosmos will extend down this margin. I love this acreage and play that Kosmos have got into in Mauritania and Northern Senegal."

Cairn has been drilling in the "SNE" field offshore Senegal, with a discovery thought to be 500m barrels of oil.

After drilling the Hippocampe-1 well in offshore Mauritania at the end of August 2017, Kosmos will drill the Lamantin well, which is also another 2-3bn barrels prospect, Mr Hodgson said. After Lamantin, Kosmos plans to drill Requin Tigre ("Tiger Shark") on the border of Senegal and Mauritania, which could be 60 TCF, i.e. 10bn barrels of oil equivalent.

"There are occasions when people have bumped into 10bn barrel fields in the last decade, but they really come around every 10 years," he said. "This is extraordinary potential that Kosmos have got into."

Kosmos' Tortue discovery in Mauritania is something like 20 TCF of gas, or 3.3bn barrels of oil equivalent. "They've stepped out



Dr Neil Hodgson, executive president Europe and Middle East, Spectrum

here and coming out to explore these features, the big basin floor fans, that form the Tortue discoveries. I think that's the future for our industry," he said.

The exploration success rate for basin floor fans is typically 1 in 3, much higher than the 1 in 10 success rate commonly seen for exploration on the continental shelf. The basin floor fans are "big, closed by movement of a plate, so relatively low risk plays," he said.

"When you are quite close to the shelf, you have a big sediment pile that sits on top of your source rock, that will push your source rock into the gas window," he said. "So we'll find a lot of gas close to the shelf."

"But as we come away from the shelf, the cover on top of the source rock gets less and less. We'll move out of a gas window into an oil window."

So "not only will those prospects be big, but they'll also have the better potential of being oil. Just think what difference that will make to countries like Senegal and Mauritania."

Also in Senegal, Cairn Energy has been drilling on the edge of a carbonate platform, exploring for oil.

A seismic line was recently presented at a Petroleum Exploration Society of Great Britain

/ Houston Geological Society conference on African E&P, and showed that the closure is a pre-Miocene unconformity (PMU).

The question is whether there might be similar analogues on the same margin.

Guinea Bissau

Looking further South down the margin to Guinea Bissau, the margin looks almost identical, with sands prograding to the edge of the carbonate platform.

There is a diapir (domed rock formation) play fairway which has been drilled, finding a reservoir with 350m of sand, in an upper and lower package. The upper sand progrades to the unconformity, making a trap similar to the one on the SNE well (offshore Senegal).

“This potential Cairn have unlocked isn’t just going to work in the area around the SNE, it’s going to work in the Gambia, It’s going to work all the way down into Guinea Bissau,” he said. “I predict that we’ll find many more billions of barrels as we continue exploring the trend towards the south.”

There have been one or two wells drilled on the edge of the transform margin which didn’t work, “so we don’t always get it right. When we are drilling for constrained channel plays it is really hard to get it right,” he said.

“We’re pleased that in Côte d’Ivoire, Anadarko seem to have some success. They found oil in this analogue type of play. So there is something going on.”

Gabon

Looking further down the coast, Mr Hodgson’s seismic company Spectrum is very interested in Gabon and recently started a 3D seismic survey in the country. The Ogooué-Maritime Province, onshore in Gabon, has “lots and lots of oilfields.”

Some people say, there’s no point in acquiring any more seismic data, because everything will have already been discovered, he said.

But “when I look at the vintage of wells in this area, with the exception of two, they were all drilled before sequence stratigraphy was invented. The only thing these lads did in the late 1960s to 1980s was drill the bumps, which they could see on the seismic we used to have.”

“And when they drilled the bumps, they found oilfield after oil field after oilfield. Each bump has an oilfield, one of which is 600m barrels. That’s all anyone’s ever done.”

“Only two wells have been drilled in this century, one was an appraisal well here that worked, the other was an oilfield,” he said.

“It’s a theme we could take to lots of mature parts of the world that haven’t all been thought about for maybe 40 years. Reworking that data, coming up with new ideas, is the way to breeze through it.”

One reason the area has been overlooked is that the seismic data looks very different when it is viewed in depth rather than time. When looked at in time, the stratigraphic

layers go upwards towards the shelf, with no traps being visible. But when you convert it to depth, you can start to see structures and stratigraphic plays. “There’s lots of plays that just needs to be re-looked again,” he said.

Namibia and South Africa

“When I started in the industry, I was warned that source rock is the issue in Namibia,” he said. But HRT, a Brazilian oil and gas company, drilled 3 wells a few years ago, and “each well found a couple of hundred metres of source rocks.”

Some people say that there’s no sand in the basin, although it is right next door to the Skeleton Coast, which has many sandy beaches and dunes. “So it’s a sandy basin, it’s an area where there is a working source rock. We haven’t just drilled any wells into it yet. Watch Namibia.”

In South Africa, there’s a well which Total is going to drill in the Southern part of the Outeniqua Basin. “It is an important well because it will work,” he predicted. “There are basin floor fans - you can see them down into the southern Outeniqua basin.”

Mr Hodgson showed a seismic image, which made it clear that there were big bright events with flat spots, an indicator of hydrocarbons. “It is pretty likely they are going to find some hydrocarbons there, which I think will open that part of the basin again,” he said.

“Perhaps if Total get lucky exploring for flat spots and find some hydrocarbons, this will be the hot area for the future,” he said.

Finding Petroleum



Kosmos Energy – success in Northwest Africa

Kosmos Energy is one of the world's biggest oil and gas exploration success stories, involved in 2 out of the 3 major deepwater cretaceous basin discoveries over the past 10 years. Paul Dailly, SVP exploration, explained how it does it

Kosmos Energy is one of the world's biggest oil and gas exploration success stories, involved in 2 out of the 3 major deepwater cretaceous basin discoveries over the past 10 years.

The region was viewed as a bit of an "exploration graveyard" in the 1980s and 1990s, with blocks often held by small companies & a string of sub-commercial wells, said Paul Dailly, SVP exploration with Kosmos.

But today it is one of the hottest exploration plays on the planet. "2 out of the 3 major deepwater cretaceous basins in the world have been opened here, in the last 10 years," he said.

Those were the transform margin where the Jubilee discovery offshore Ghana was made and the Tortue discoveries to the North, up in Mauritania. Kosmos has been involved heavily in both. (The third discovery was in Offshore Guyana).

"Some of the things we're learning, we think, bodes well for future exploration plays. We think there's a lot of future potential in Northwest Africa and West Africa generally."

The region is of course vast, with three big continental margins with different structural and tectonic histories.

Kosmos has been focussed on the area since its formation in 2004, and drilled all of its 21 exploration wells in the area. It also has 2 blocks in Suriname (South America), adjacent to the giant Lisa discovery, on the basis that geology and plays are similar.

Kosmos sees the transform margin "from a technical perspective" as continuing further around the West African coast beyond Nigeria, including Cameroon, Equatorial Guinea to North Gabon. The company sees lots of similarities between play systems in São Tomé (an island off Gabon), Ghana and other parts of the transform margin.

The company is taking a lot of lessons from the exploration in that part of the world which are useful in understanding the transform margin further north.

North West Africa is still "relatively unexplored", with only 400 exploration wells, over a very large area, he said. "The explora-



Paul Dailly, SVP exploration with Kosmos

tion drilling density is still very low. A lot of people have left the basin, and once again it has become unfashionable. So that's a great opportunity to get back in."

Some areas have got a "bad rap in the recent past. "The follow up exploration to Jubilee was not very successful," he said.

Overall, drilling activity goes up and down as the oil price goes up and down. "That's true here as well as everywhere else."

During the 1960s to the early 1980s, there was a "reasonable amount" of exploration activity, mostly on the continental shelf.

In the early 1990s the drilling focus moved to the Niger delta and deepwater Angola, where the industry was "very successful" during the 90s and early 2000s, drilling tertiary reservoirs (65 million to 2.58 million years ago) off West Africa, this resulted in a decrease in exploration in the Cretaceous margins. The discovery of Jubilee in 2007 re-awakened the industries interest in the Cretaceous transform plays and drilling activity increased as a result.

Kosmos background

Most of the original Kosmos management team met in the 1990s while working at a company called Triton Energy, which was acquired by Hess in 2001. Triton Energy had been one of the first companies to see the potential of the late cretaceous play, Mr Dailly said, finding oil in Equatorial Guinea, the first "real transform play."

When the team started Kosmos in 2004 to 2005, they tried to extrapolate some of this understanding to other areas of the transform margin.

The Jubilee field, offshore Ghana, discovered in 2007, was the second big transform play discovery. It led to a big increase in oil industry activity. It was followed by successful exploration offshore Mauritania and Senegal, by both Kosmos and Cairn Energy.

During 2017, as the oil price has started to recover, there has been a "bit of a frenzy of activity to pick up acreage in these basins," he said. There have been 400 wells drilled around NW Africa, which is "really not a lot of wells for an area of that size".

There has been a low commercial success rate, although it has improved since 2000.

Kosmos has drilled 21 exploration wells in North West Africa, and made 8 discoveries, so a success rate which is "pretty good in these frontier plays," he said.

The company has aimed to not follow oil price cycles but instead to "stick to our knitting through highs and lows," he said. It has also kept a geographical focus. "I think that's an important reason for us continuing to be successful."

The size of the discoveries basically comes down to the "extent of these basin floor fans," he said. Kosmos has been mainly exploring "slopes" for the past 5-10 years, but now it is doing more exploring in basin floor fans, where the reservoirs can be much larger.

In April 2015, Kosmos Energy made a play-opening gas discovery in Mauritania's offshore Block C-8 with its Tortue-1 well. The Tortue field is a giant deepwater gas field straddling the border of Senegal and Mauritania.

As Kosmos drilled it, it realised that it isn't a "conventional trapping geometry", but a "stratigraphic trapping geometry", aided by the style of deposition in the reservoir. "They are not just straightforward deepwater channel reservoirs," he said.

The 'non-conventional stratigraphic traps' are created due to the way the sands are deposited and so it is important to understand the stratigraphy from a trapping perspective as well as a reservoir perspective.

Kosmos has discovered about 8bn barrels of oil equivalent, and a lot of that is gas. The gas resources are big enough to be commercially attractive.

Kosmos' business

Kosmos Energy is entirely focussed on the exploration and early development side of the E&P business, where it believes that most value in the industry is created.

The value is only monetised if the fields can be developed, "but that requires a scale of organisation that we don't have and don't particularly want to have," he said.

"We've taken a conscious decision to have a relatively small company which focusses on the front end, and just make sure we get very good strategic aligned partners to execute on the second part of it."

In the Jubilee field, Tullow became the "production operator", coming in to run all the operations, while Kosmos was the "development operator", and alongside the other partner's, GNPC & Anadarko, the group worked together to bring the field onstream in 42 months.

At Tortue, "our hope is that with our partners BP we can do the same thing in gas terms," aiming to get on stream in 6 years.

The Tortue discovery is "probably about 8 bn barrels of oil equivalent, 20 TCF," he said. "We've only drilled 3 or 4 prospects out of an inventory of 20 prospects."

The business model is driven by maximising value creation. "That drives us to certain basins and certain portfolio shapes," he said. "We only go into basins where the fiscal terms are good enough that if we find something we're going to create a lot of value. You can't really go to technically lower risk basins such as Angola or Nigeria, and create the same amount of value because of the terms."

"If you are going to go to frontier emerging basins, you've got to do it in a way where you can manage the risk. But you get the terms, so that in the case of success, it will work even at a low oil price."

"We keep that risk low by having the right people. Exploration excellence is how we think about that."

The Tortue discovery is a big gas province, but it is so large that "we think, even in to-

day's LNG world, it will be competitive when it comes to market, in the early to mid-2020s. The breakeven cost is relatively low and the resource is big enough."

The company has a "clear and consistent strategy," based around "generating new ideas in old basins and places which haven't been focused on in the past."

The company keeps focused on the central and northern part of the South Atlantic, although it has taken some assets in the North Atlantic in the last couple of years and then got out of them.

The company only has 4 or 5 "positions" around the world. "That's about all we can manage technically," he said. "There's about 30 people in the exploration department, about 25 geoscientists. We don't want to get too much bigger than that."

"It is important that the leadership knows the portfolio and is calibrated to the risk of that portfolio."

With higher risk positions, you need big footprints (a larger license area), in case you discover that a prospect or even a play is slightly different to where you thought it was. "What we'll tend to do is try to build 4 or 5 big footprint positions - independent petroleum systems where we think we can manage the risk."

The company has drilled 25 wells over 10 years with a play opening rate of about 1 in 3, a good success rate in frontier and emerging basins. Typically they drill 2-4 exploration wells per year. "That's about the level of activity that the balance sheet can stand," he said.

The company needs to make sure there is "parity between the technical side and the financial side" of the business.

After the Jubilee discovery in Ghana, "this play became too hot for us to participate in," he said. We didn't feel very comfortable with that. So we stepped out of the area and tried to leverage our understanding of that part of the world into other places."

"Over the life of the company we spent about \$1.4bn dollars, to find net reserves of about 1.5bn boe. So discovery costs of about a dollar a barrel. So we've had a good commercial success rate, which is obviously critical."

The company continues to build its position in the transform margin, including the transform margin of Latin America. In 2011, the com-

pany took a position in Suriname, in northern, South America, which has similar geology to North West Africa because the two areas were joined together until 140mm years ago when the Atlantic started to open. However following Jubilee a lot of unsuccessful drilling resulted in many companies leaving the transform margin, despite this it remains a core area for Kosmos.

Processes

With a small team of people, the company's processes can be kept simple.

"Having the right people is the key thing," he said. "We started off with an experienced set of explorers. We've got about 5 or 6 people who worked together for 20 years in this geography. Then we slowly introduced additional people, brought in younger people. We are still a tight knit group."

"The important thing is to try to leverage knowledge gained from one idea into the next idea."

In that way, the concepts originally developed with the Ceiba discovery) could then be used in the Jubilee discovery, and that should also help find resources in Sao Tome or Suriname. "One of these plays will allow us to introduce the next stair step in the evolution of the company," he said.

The company needs to continue to develop new frontier play concepts, "Otherwise we will get trapped in following other people's success. That is a very difficult thing to sustain and create a lot of value in."

Although there was a lot of failure in the transform margin after the Jubilee discovery, there are a number of lessons we can learn from that. "As an industry we can learn as much from the things we don't do so well to leverage into the future," he said.

"We try to stick very much to basins we've committed to and try to make the most out of investments we've made," he said. "As an industry we are guilty, especially in high oil price cycles, of being opportunity driven and exploring in an ad hoc fashion."

"We did see, and occasionally still see, a lot of ephemeral exploration with companies not really committed to the basin, drilling a couple of wells and leaving without really digesting the results of the drilling they have done. We think that can be a real problem."

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2017 onwards

During 2015 & 16, Kosmos drilled the “mid-slope anticline trend” offshore Mauritania and Senegal. It is now moving to look at basin floor trends, “which is why you see these big numbers in the prospects.”

In May 2017, Kosmos announced a major gas discovery offshore Senegal in the Yakaar prospect, in a license block which Kosmos and BP hold the equity.

“We’re drilling out a huge amount of inventory between ourselves and BP,” he said. “We’re drilling 4 wells [in 2017], that’s the most of any operator in West Africa.”

“So, a very active exploration program. We’ve got hopes for opening up new plays, and coming up with new ideas we can leverage around the margin,” he said.

Offshore Senegal and Mauritania counts as “one of the world’s hotspots”.

Another hotspot is across the Atlantic, in Guyana and Suriname, which is about to get drilled.

“Going forward, we still think that we’re learning a lot and it is pretty early days for Cretaceous plays in West Africa,” he said.

Deepwater drilling has proven surprisingly effective. “Since we started to drill wells in greater than 2000m of water, I think everyone’s been surprised by how hot everything is.” Exploration in the past was “pretty much ending where people said the continent - ocean boundary was.”

“The more we look at it, the more opportunity we see in terms of trying to expand source

kitchens out into deeper water, maybe even to oceanic crust. The capacity to find trapping geometries is probably much greater than a lot of us thought.”

“Kosmos is still very excited about deepwater conventional exploration. It’s not very fashionable, I think if you do it well and stick to your knitting you can be very successful at it.”

Audience questions

Asked about source rock in Mauritania, he said, “I think there’s something other than the Cenomanian–Turonian and Albian working and producing the gas. We don’t think you can generate huge amounts of gas from [these]. So we think there’s an older source rock, probably early cretaceous. There’s a huge thickness of early cretaceous sediment out there.”

Mr Dailly was asked what is the most important consideration when analysing a new basin.

He answered it is the “geologic fundamentals really,” the company puts a lot of emphasis on putting together source rock models, trying to understand the thermal history and crust as well as possible. “We just keep in mind that while we may have a couple of basin models – there may be many other basin models that are also possible. We don’t get too hung up on that stuff.”

A critical point is the integration of data and trying to understand where the sweet spot may be, and determining what size position to try to take. “Quite often it is difficult to do that in a basin where there’s a lot of people looking,” he said. “We try to do it in basins where we can pick up a good position and to help us manage the risk.”

Also, early in the evaluation Kosmos doesn’t focus on trap definition, because “you don’t tend to see them on older, poorer quality 2D or old 3D surveys. We put more emphasis on play elements and tend to look for are the sorts of structural elements that might make traps down the road,” he said. “We are prepared to take more trap risks than a proven basin explorer would, who is used to seeing traps and flat spots.”

The company will spend money on a high-resolution 3D seismic survey upfront.

Mr Dailly was asked how hard he finds it to get “decent terms” from African governments.

“Right now it is very difficult. We’ve all realised that we can’t afford to explore on the terms available,” he said. “Governments take a long time to adjust their expectations,” and with the oil price crash, “they have a lot of other concerns and are having to manage with smaller budgets”.

“We’re beginning to see governments recognise that they need to change the terms. The difference between recognising and actually doing it is taking longer than hoped.”

Mr Dailly was asked if there was any pattern to the reasons that wells failed. The answer was mainly reservoir, he said. “We found [hydrocarbons] but we didn’t find it in the commercial quantity that we needed.”

“In Ghana, in addition to the giants we ended up with a number of sub-commercial discoveries. Some of them might [work as tiebacks] but they won’t stand alone,” he said.

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Impact Oil and Gas in Gabon

Gabon is a new frontier in exploration – Phil Birch of Impact Oil and Gas explained why he thinks it makes sense

Impact Oil and Gas recently took a block in Gabon through a license round. The company believes in Gabon because it sees it as a continuation of the same geological trend where the SNE field is found (within the Senegalese portion of the Mauritania-Senegal-Guinea Bissau Basin, further to the North), said Phil Birch, exploration director of Impact.

“We end up going to some places which might not be very trendy, but those are where the opportunities lie and where the geology drives you,” he said.

Buying in a license round is an unusual and expensive way for a ‘junior’ company to get involved in a region, he said. The company is exploring together with CNOOC NEXEN.

Gabon is in West Africa, on the Equator, with Nigeria, Cameroon and Equatorial Guinea to the North, and Central Africa Republic, Congo and Angola to the South.

Impact is looking in very deepwater. “We’re on the edge of what is drillable,” he said.

Impact Oil and Gas is a “small private exploration organisation,” developing a “large mainly deepwater position”. It has a large acreage position in South Africa, in the Durban basin, together with Exxon and Statoil, and a deepwater position offshore South Namibia and the Orange Basin of South Africa. It is looking for deepwater fans, similar to the ones which Kosmos is exploring for in North West Africa, in both size and geological aspects.

Gabon is historically one of the biggest producing countries in Sub Saharan Africa. The first oil discovery was in 1931, and a company which later became Elf was looking in Gabon’s jungles for oil in 1922. Production started in 1957.

The first major discovery was the Gambia onshore field by Shell in 1967. This was a pre-salt field, very hard to see with seismic. “Thinking about seismic technology in the 1960s, I think it was found more by luck than by seismic technology to be quite honest.”

Improvements in seismic imaging technologies in the 1980s allowed Shell to discover Rabi-Kounga, a pre-salt onshore field, in 1986. “That dwarfed everything.” It was in the same Eastern basin as the Gambia field.

National production for Gabon peaked at 357,000 bopd in 1996, and the forecast for 2017 is just 220,000 bopd. Today, “Gabon has dropped down to 5th place in the Sub Saharan pecking order of producers, being overtaken by both Equatorial Guinea and Congo. The reserves are reducing all the time to less than 2bn barrels today.

Oil provides the biggest revenues for the country, and the government is very keen to improve production, with a target to achieve 250,000 bopd in 2020, and “incredibly ambitiously” double it by 2025.

“Maybe with new strategies, new seismic, perhaps this will resurge again,” he said.

The Gabon government is “clearly motivated to open this area - with its huge potential,” he said. “It is doing that - finally it is changing the fiscal structure. This will make deepwater exploration in Western Gabon much more exciting for all of us, and more commercially viable.”

There were a few more presalt discoveries after Rabi-Kounga, “but they were never very big.” The question is where the next big pre-salt discoveries might be, he said. Rabi-Kounga could be a good place to start.

Looking at Rabi-Kounga

Mr Birch showed a simplified image of an East-West cross section of the Rabi-Kounga field.

There is a graben (a depressed block of crust bordered by faults), with the biggest part on the Eastern side.

Some of the sections of the graben are inverted (pushing the rock upwards rather than letting it fall downwards). It was inverted during the middle Aptian era.

After this, there was a thick lacustrine (meaning: from lakes) deltaic deposit on top of it. The inversion structures were chopped off.

There was a marine transgression (where sea level rises relative to land, and covers the land), releasing organic matter which now serves as the source rock. This “was a fantastic sponge to put over the top, lovely porosity, fantastic permeability,” he said.



Phil Birch of Impact Oil and Gas

There were some other “little” stage of inversion on the main graben bounding fault.

It leads to the “size of field that we have today”.

The field has a STOIIP of 1.7 to 1.8bn barrels (based on 42 per cent recovery). The peak production was 217,000 barrels a day in 1997, down to 150,000 in 2010.

So Rabi-Kounga is a “fantastic field, a fantastic analogue and a fantastic learning point for us to extend our thoughts around Gabon,” he said.

The field is chopped up by transform faults, which go through the whole of Gabon.

Recent developments

Recently, ENI geologists used high quality 3D, Prestack Time Migration (PSTM) seismic to go through the basin. They could see large gas and condensate discoveries associated with the thick, pre-salt sedimentary sections.

ENI’s 2014 “Nyonie-Deep” discovery, the North, offshore but close to shore, is reported to have more than 3bn barrels of oil equivalent in gas and condensate, with a 200m thick section of Gambia sand.

The thicker the sedimentary rock above the reservoir, the deeper the heel of the reservoir, and the deeper the lacustrine source rocks, which means they are more likely they are to be in the gas and condensate window. “That was a very important learning point,” he said.

Another important learning point was to learn how far west (offshore) the play extends. Ex-

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plorers originally thought the reservoir would get thinner and thinner as you go offshore, eventually thinning to nothing.

“But we were proved totally wrong. Total proved in 2013, just before ENI, that actually this play extends much further west, with 55m of net gas and condensate sand,” he said.

Then in late 2014, Shell and CNOOC discovered Leopard, on the outer high of the continental crust (the opposite side of the Graben, formed in this case by volcanics).

Shell could use the seismic to see that there is a thick sedimentary crust, and over 200m of gas and condensate.

Based on this, Impact thought there might be an opportunity on this outer high further south. “We’re exploring that acreage at the moment, it is show some early expectations,” he said.

“Also in that same licensing round, we had Repsol and PETRONAS acquiring blocks as neighbours,” he said.

“In our PSC (Production Sharing Contract signed with the government) at Impact we argued that since we are little business, we shouldn’t need to have an exploration well in the first exploration phase, so please let us off, and drill in in the second phase,” he said.

“However, Repsol and Petronas are having to drill in the first phase, they will drill at the end of 2017. It’s going to be very interesting. We are waiting for those imminent Repsol and Petronas wells to go down and de-risk our well commitment,” he said.

Shell showed the Leopard discovery at a conference in Capetown in 2014. There is a massive structure sitting on top, with autochthonous (formed in present position) salt and allochthonous salt (originated in a different position) on the top. It shows that the reservoir is sealed by cretaceous shales as well as by salt.

Analogues

Impact looked for a geological analogue to the Gabon basins, to help understand it. One

possible analogue was the East Africa rift system, looking between the Western and Eastern branches of the East Africa rift system.

In Gabon, like in the Eastern side of the East Africa rift, there was a fault on the basin to the East, and a thickening to the west, with the heel of the basin (point of thickest reservoir) right at the western edge of the basin.

In Gabon, since the rifting, the area further to the west went into ‘hyper extension’, giving many low angle fault systems, leading to an outer marginal trough (as South America moved away). This could also be a reservoir.

This outer marginal trough grew quickly in the Albian, with a huge thickness of marine sediment, probably very organic marine shale, he said. There is also salt onlapping over the top.

Another possible analogue is in the conjugate margin of the Camamu Basin offshore Brazil, where there is a similar age rift (Barremian-Aptian).

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Spectrum – understanding crust key to understanding geology

In East Africa, understanding the crust, and whether it is oceanic or continental, can be key to understanding the geology and where to find oil, said Karyna Rodriguez, director of geoscience with Spectrum.

In East Africa, understanding the crustal architecture, and whether it is oceanic or continental, can be key to understanding the geology and where to find oil, said Karyna Rodriguez, director of geoscience with Spectrum.

Ms Rodriguez's talk looked at projects to understand crust in three areas of interest for hydrocarbons - Durban basin (South Africa), JMA (joint management area) between Mauritius and the Seychelles, and Somalia.

East Africa is mainly known for its gas discoveries, such as in Tanzania, with other gas discoveries to the North and onshore, and a lot of gas indications, she said.

But there are also really important indications of oil, such as in the Lamu basin and the 2014 Sunbird discovery both in Kenya. There are large onshore oil fields in Madagascar. There are oil and gas shows in the Seychelles, with tar balls, and oil indications from wells that have been drilled.

Durban basin

Spectrum did a project to see if it was possible to identify the types of crust, working with an MSc student at Leeds University (UK), using Spectrum seismic data, together with gravity data recorded from a ship.

The area of study was offshore, south of the Northern Natal valley, west of the offshore Mozambique Ridge.

The tectonic history includes the breakup of Gondwanaland (180 to 170m years ago), the rifting of continents and activation of Agulhas-Falkland Fracture Zone (AFFZ), a huge transform fault (153 to 136m years ago) and volcanism forming the Mozambique ridge (140m to 128m years ago), largely interpreted as over thickened oceanic crust.

For petroleum exploration, you need to establish what type of crust you are dealing with (continental or oceanic). Both oceanic and continental crust can have sediment, but the heat flow variations can have a major impact on hydrocarbon generation.



Karyna Rodriguez, director of geoscience with Spectrum

Petroleum geologists also want to get an idea of the geothermal gradient (how much temperature increases with depth, and so whether oil or gas is likely to form), and if there are any source rocks in the area (providing the hydrocarbons).

Ms Rodriguez showed how one of the seismic lines across the region, going out to sea perpendicular to the coast, had been interpreted, picking out the sea floor, top of the basement rocks, the Moho (boundary between the earth's crust and mantle, named after Croatian seismologist Andrija Mohorovičić).

The Moho stops close to the land side of the line, and the point where it stops could be the point where the oceanic crust changes to continental crust. There could be a fault at this change point, perhaps the AFFZ (Agulhas-Falkland Fracture Zone).

But there are uncertainties in the area. Neither side of this change point really looks like oceanic crust, although it is not thick enough to look like continental crust, she said. It could be over thickened oceanic crust, which can also be seen on the Mozambique ridge, or something else.

Taking a seismic line perpendicular to the first, running along the coast and intersection the first line at the point where this fault is thought to be, it looks like rifting features, and it looks much more like stretched continental crust.

The researcher put together two models, one where a mystery section is continental crust (with layers of volcanics, middle and lower crust) and the other where it is over thickened

oceanic crust. Then taking the shipborne gravity data and comparing the observed gravity with what the gravity would be if the model represented reality, he found the first model fitted much better (continental crust with volcanics).

Once you have concluded that it is continental crust, you can develop a better geothermal gradient model and work out if you might have oil, she said.

JMA - Mauritius and Seychelles

There hasn't been any exploration in the so called "Joint Management Area" (JMA) between Mauritius and the Seychelles since 1970s, although it has shallow water, and has a friendly government with friendly terms on offer to oil companies, she said.

There are not many tectonic models covering this region.

Ms Rodriguez looked for technical papers which talk about the detachment of the JMA continental crust from both India and Madagascar, and only found one article (from GeoExpro magazine in 2006).

In the breakup of Gondwanaland, 200m years ago, a portion of continental crust which underlies the Seychelles / JMA became detached from both India and Madagascar. From that it was a separate fragment of continental crust, and the Karoo sediment developed on top.

The Karoo sedimentation can be seen on seismic for the Seychelles and the JMA, further proven by drilling on the Seychelles.

Then 60m years ago, India started drifting from Madagascar, with the JMA in between India and Madagascar.

The question is whether the crust in the JMA is oceanic or continental. But from knowing the crust is 60m years old, using a well trusted graph from measurements around the world, the oceanic crust should be about 5.5km depth. The crust here is under 2km depth. "So we strongly believe this is not oceanic crust," she said.

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The gravity data in both the Seychelles and JMA area is much lower than for the oceanic crust around it, also suggesting it is not oceanic crust.

The next question is whether there could be hydrocarbons in it.

In 1975, Texaco drilled the Saya de Malha-1 well in the JMA, going through 2424m of limestone, then penetrating basalt, and drilling 840m of basalt before the company stopped. Another well, NB-1, in the south, found a similar sequence.

However the basalt was dated 30m years old. Since the oceanic crust is 60m years old, this was probably not oceanic crust.

Looking at it with modern seismic, together with seismic company Bridgeport, and developing some gravity models, showed that the basalt has variable thickness, with an interesting Cretaceous section below. The model and seismic showed the basalt was unlikely to be thicker than 1.5km. "I don't think anyone would want to drill 3km of basalt," she said.

With further studies including gravity showed that the Cretaceous section could include a charge (Karoo, Jurassic, Cretaceous source rocks), a reservoir (Karoo, Jurassic and Cretaceous) and a seal (Cretaceous and Volcanics).

There is also a slick above detected from satellite imagery, which could be evidence of oil.

Somalia

Spectrum acquired 20,000km of 2D seismic offshore Somalia in 2015, adding to another 20,000km acquired in 2014.

This is a "very frontier margin". Somalia had a civil war starting in 1991, and during this time much of the data was destroyed.

"There is a new government we believe government is really committed to oil exploration and reviving oil industry in this area," she said. It has commissioned two regional 2D surveys.

The basin evolution starts with Gondwanaland rifting 200m years ago, in the late Carboniferous to early Jurassic, with Karoo deposition. In the early Jurassic there was a breakup of Somalia and the MSI (Madagascar, India, Seychelles) block – with seals and reservoirs being deposited during this time.

In the mid to late Jurassic, the MSI block drifts south, there is a relative rise in sea level, and carbonate deposited.

In the early Cretaceous, India starts moving away from Madagascar.

At the end of the upper Cretaceous there was a global "anoxic" event (with oceans depleted in oxygen) and some marine shales being deposited, making good reservoirs and good source rocks.

In the late Cretaceous, India pulls away from the Seychelles and rotates, and the anticlockwise rotation might have something to do with the uplift erosion seen in Somalia, and deposition of other source rocks, and deposition in the grabens which open up. This is a time of deltaics, turbidite fans, carbonate reefs and shoals.

In the Paleogene, Northern Somalia is more dominated by carbonates, and Southern Somalia more dominated by clastics.

From an oil and gas exploration point of view, the question is what are the source rocks, what type of crust do they sit on and are they mature for oil and gas.

Spectrum has done some gravity and basin modelling of the area together with Leeds University, which helped gather a good understanding of the crustal architecture and thermal maturity. There are strong indications that Somalia is an oil-prone province with huge unexplored potential.



Lyme Bay – accelerated interpretation and early visualisation of geology

Lyme Bay Consulting of the UK has developed the Detailed Reconnaissance Study workflow that allows rapid interpretation of every reflector in a 3D seismic volume.

Lyme Bay Consulting of the UK has developed the "Detailed Reconnaissance Study" workflow to work with any seismic volume, in time or depth, that rapidly and accurately identifies all the structural and stratigraphic features in the volume. The method enables you to map the full volume early and visualise the entire data set, including seismic attributes, in a matter of weeks.

Gerrard Spear, geoscience director, Lyme Bay Consulting, presented an examples of DRS results from a data set from the AGC Central block, offshore between Senegal and Guinea Bissau.

The data set was commissioned by ORYX Petroleum of Calgary. It was acquired by

BGP and processed by Downunder Geo Solutions and managed by geophysical consultancy GeoPartners Ltd.

Mr Spear is a former consultant geophysicist with BG, among other roles.

Discoveries in the region include Cairn Energy's FAN-1 and SNE-1 offshore Senegal, and heavy oil discoveries in the AGC Shallow block, "Dome Flore". So there is evidence of a working hydrocarbon system. There is also West African carbonate trend running through Mauritania, Senegal, Gambia and into the AGC central area.

There are various play types, with carbonate platforms, lower cretaceous sediments, deep-

water fans, and various methods of charging.

The Lyme Bay workflow maps every reflector in a seismic volume, working on the entire record length in 3D. It generates a 3D geological model based on the input seismic data. From this typically there would be about 250 horizons generated on which any and every attribute can be draped and viewed in a horizon consistent manner.

By mapping early the geoscientist can see all the prospectivity of the data set and begin to understand the risks and mitigations required to further understand prospects.

This avoids a common problem of a geophysicist seeing something interesting but

not finding the time to look at it in detail.

The input data is SEG-Y seismic. Lyme Bay Consulting will condition the data if there is a high noise level (older data or onshore data) and can constrain the model with both a fault network and specific horizons if required, such as major unconformities, to generate the best final GeoModel.

Mr Spear showed an example of a data set from Geopartners, showing the Lower Senonian (upper cretaceous) unconformity. This Lower Senonian unconformity is an important feature all the way up the East African coast, he said.

Examples were shown of blended volumes including reflectivity, Seismic Relief and

Structurally Oriented Semblance that allows accurate and detailed fault interpretation, important in this area as there are a series of extensional faults that set up the structures in this area.

You can visualise your 3D volume using attributes in other ways, using different colours to bring out the (for example) RMS amplitude, Structurally Orientated Semblance and blended Frequency Decomposition.

Trends in these attributes can be viewed in a montage to help understand the geology and stratigraphy as they are often more enlightening than just the reflectivity data alone. Relating a potentially interesting feature from one attribute to another helps reinforce its potential, and having the feature already

mapped allows the building of a lead portfolio very quickly without missing any potential in the data.

Several interesting and prospective examples of structures and associated stratigraphy were shown from the data set.

Altogether, the 1920 km² seismic volume of the “AGC Central” region was processed in under 4 weeks, delivering 300 horizons, SEG-Y attribute volumes, and multiple hydrocarbon leads along a prolific play fairway.

The final Multi-Client PSTM and PSDM volumes are now available for license through Geopartners, he said.

PGI – border disputes and security in Sub Saharan Africa

Two big threats to oil and gas operations in Sub Saharan Africa are border disputes, particularly offshore, and security risks. Tom Bacon of consultancy PGI gave an overview

Two big threats to oil and gas operations in Sub Saharan Africa are border disputes, and security issues. Other issues are government gradually trying to take control of operations, or government incompetence, said Tom Bacon, head of risk analysis with London consultancy Protection Group International (PGI).



Tom Bacon, consultancy PGI

But there is enormous social and political diversity, and variations in political stability and security across the region, he said.

At the heart of many issues is the importance of oil revenues to many governments, generating 90 per cent of all export earnings in Angola, Nigeria and Gabon, for example, and generating 50 per cent of GDP in Angola.

Rather than just see risk as something to

avoid, and security as a cost, companies can take a strategic approach to risk. At the board or shareholder level, they can decide what level of risk tolerance they want to have, and then act accordingly.

To aid this understanding, PGI publishes risk index of different countries, so you can compare the different risks between countries, and monitor how they are changing.

Border disputes

There has been a dispute over the maritime border between Ghana and Ivory Coast, and so whose country certain oilfields lie. This dispute led to an impact on the share price of Tullow Oil, because the company was forced to delay exploration activities, he said.

There are also disputed waters between Kenya and Somalia, which is leading to delays in issuance of exploration licenses.

Within Tanzania, there have been disputes over how many money is given to local authorities and how much goes to the Tanzanian government, which has had impacts on exploration.

There are strong hostilities between Puntland and Somaliland, and contested blocks. “It looks like that’s going to be a very dif-

ficult dispute to resolve.”

Somalia has conflicts over licenses, with a number of exploration licenses issued before civil war in 1991, and new licenses being issued over the past 5 years, leading to a number of competing license claims.

The Mogadishu government also has disputes with regional authorities over who has the right to issue license blocks, and the legislation is extremely vague.

Governments

In many countries, the revenues from oil and gas have helped keep governments in power and blunted political form – some examples of this could be Gabon, Equatorial Guinea, Angola, Chad, and Congo Brazzaville. In the case of Equatorial Guinea, and until recently Angola, the leaders had been in power for over 30 years.

Many of the government institutions have bloated bureaucracies and also not much competence in working with international oil companies.

The risk of governments taking over oil and gas assets is low, but you can see “creep” of gradually changing terms, leading to national oil companies gradually gaining higher stakes and royalty allocations. This

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creep might be seen in changes in terms of production sharing agreements (PSAs), or local content laws, making requirements to use increasing numbers of local workers or suppliers.

It is important to consider if there are any legal or arbitration channels for resolving problems, such as the country having a bilateral treaty with your own country, or the country being a member of the International Court for Settlement of Disputes. Within the country, the legal system can quite often be politicised, so hard to resolve disputes with government in the national legal system.

Security

The Al-Qaeda in the Islamic Maghreb (AQIM) organisation is active across the Sahel belt, but it hasn't affected too many oil production states. There have been activities in Côte d'Ivoire, and threats in Mauritania and Senegal. The problems with AQIM are more in countries which are more involved in mining, such as Mali, Burkina Faso and Niger.

Boko Haram is a key consideration in Nigeria and the Lake Chad basin, affecting Chad, Niger and increasingly Northern Cameroon. The organisation's strength and activities have declined considerably in the past 2-3 years, but there has been a

revival of attacks in parts of Nigeria. During the early 2017 the group expanded into countries around the Lake Chad basin.

South Sudan has seen a real deterioration in its security situation, and forced companies to declare "Force Majeure" (being unable to complete their contracts due to unforeseeable circumstances).

There has been a real spike in violence in Ethiopia.

All these factors impact personal security and operational feasibility, he said.

In many countries, the military has a role within the decision-making realm of government, and an interest in several key departments of government, which can include the energy department.

There have also been a number of central African countries experiencing coups in the past decade.

Fuel theft is a further issue, with Nigeria seeing 400,000 barrels of oil per day theft at the peak, stealing oil from both onshore and offshore (piracy). This leads to a major loss of productivity for the industry overall.

Piracy has also occurred offshore Ghana,

Benin and the Bakassi peninsula on the Gulf of Guinea.

Piracy offshore the East coast, which was rife offshore Somalia in around 2010 to 2011, has declined significantly. But it isn't something that should be dismissed, especially if you are conducting offshore operations with seismic vessels," he said.

Another security threat is civil unrest, such as protest riots, anti-government grievances, and industrial action – particularly for Gabon. Gabon also had controversial elections in 2016, and has seen much political unrest.

Guinea, which is more in the mining industry than oil and gas, has seen weeks of high unrest due to a lack of electricity. Unrest can also be driven by fuel prices.

"Understanding the political cycle of countries can really help mitigate your exposure to unrest," he said. For example, Senegal has periodic demonstrations sound local elections, which recently involved imprisonment of an opposition leader.

Other security issues to consider are corruption, transparency, and ownership of land rights (for example in Somaliland, constitutionally, the government owns all land).

Finding
Petroleum



Finding Petroleum: Finding Oil and Gas in Sub Saharan Africa

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What did you enjoy most about the event?

“ “ **Networking, and new ideas in technical presentations.**

“ “ **Update on oil & gas activity and technology.**

“ “ **A good range of relevant presentations and good networking.**

David Lawton (SLR Consulting Ltd)

Andrew Zolnai (zolnai.ca)

“ “ **The first and last sessions were very informative & interesting, and gave a very practical perspective on their respective topics.**

David Harper (Harper Associates)

“ “ **Presentations and also the 'Q & A's.**

“ “ **6 presentations, all worthy of merit, and good presenters.**

“ “ **Lots of oil operators represented.**

“ “ **Excellent mix of talks covering a wide range of perspectives.**

“ “ **The unexpected discovery from both presentations and networking.**

Richard Walker (Consultant Geophysicist)

Simon Bradbury (The Steam Oil Production Company Ltd)

“ “ **High quality presentations from leaders in the independent exploration sector.**

FG Yeterian (Philax Resources)

“ “ **Ambience.**

Kieran Aust - (Suez Oil & Gas)

“ “ **High level technical papers.**

(Working Smart)

