Finding Petroleum

Understanding petroleum systems - the key to exploration success?

How source rock works - and studies offshore South Africa

Is there a giant oil field offshore Guinea?

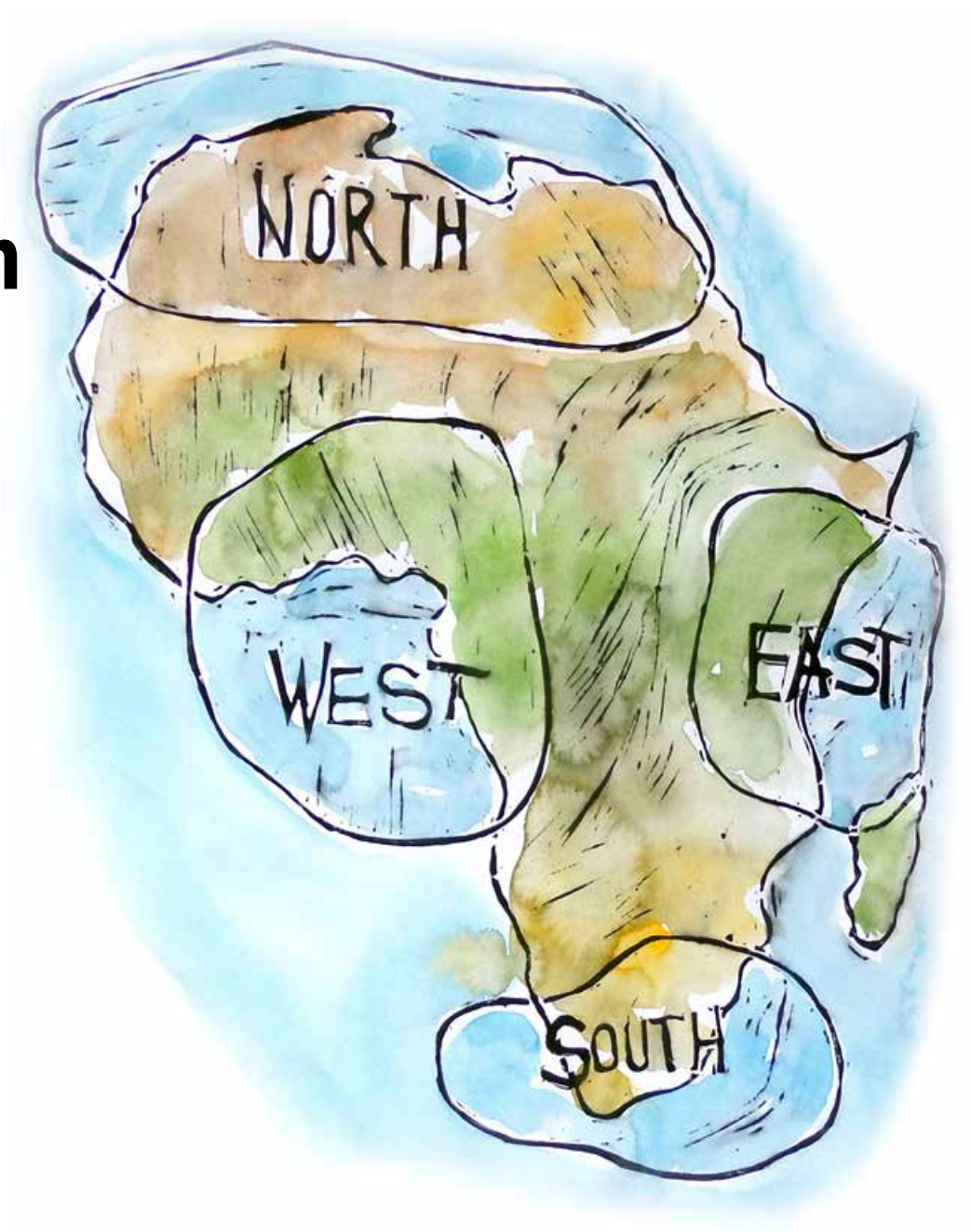
Spectrum – looking for Gambia source rocks on seismic

Why explorers need to think about ESG now too

Special report

Finding Petroleum in Sub Saharan Africa

24 May, 2019, London



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Finding Petroleum in Sub Saharan Africa – source rock, petroleum systems and ESG

Our May 24, 2019 forum "Finding Petroleum in Sub Saharan Africa" looked at better ways to understand source rock, conduct petroleum system modelling, and the emerging relevance of environmental, social and governance (ESG) issues. We also looked at whether there could be a big petroleum system offshore Guinea Bissau

Oil and gas exploration has been "dramatically unsuccessful" over recent years – and one of the main reasons could be a lack of understanding of petroleum systems as a whole, said David Bamford, event chairman (and a former exploration lead with BP), in his introduction to the Finding Petroleum forum on Sub Saharan Africa in May 24, 2019.

By understanding the petroleum systems, we mean determining if there are adequate source rocks, when and how they might have matured and expelled hydrocarbons, how the oil and gas could have migrated, and how it got trapped in reservoirs that can effectively produce.

To illustrate how understanding petroleum systems can make a big difference to exploration, Dr Bamford told the story of the Johan Sverdrup field, discovered in 2010, the biggest oil discovery in the Norwegian sector for many years.

People had seen a large trap on 3D seismic data on a marginal basin high for many years, but everybody believed it was in the "migration shadow" for maturing Kimmeridge Clay source rock, or in other words, not in the pathway of migrating oil. So oil would not end up in the trap.

But then someone had an idea that there might be another source rock behind the known one, and pursued a completely different idea. They drilled it and found the reservoir. "That story is changing the mental model people have lived with for the past 10-15 years," he said.

A second example of the importance of understanding petroleum systems was of a company working West of Shetland, which had lots of 3D seismic, onshore analogues, discoveries, a well-known structural history and sedimentology.

They believed the Kimmeridge clay was the source rock for just about all the oil in the region.

But when they did thermal history modelling in the conventional way, it showed that the Kimmeridge clay matured before the Foinhaven and Schiehallion reservoirs were formed, and which contain a lot of the oil.

There had been some hypothesis for how this could be. One theory dubbed "motel," suggested that the oil had somehow got parked somewhere else for 50 million years until the trap was available. Another hypothesis, dubbed "whoopee cushion", suggested that the pressure accumulated and then was released.

Now we know the reason, that the heat "pulse" which caused the maturing of the oil happened 50m years later than was previously thought, Dr Bamford said. And in retrospect it is clear that the motel and whoopee cushion models were nonsense.

Another example of weak understanding of petroleum systems was from French Guyana and Suriname, where one oil company did not explore the region because they believed there was a simple source rock system covering both countries.

So a discovery in Suriname would therefore prove the system was working regionally in Guyana, French Guyana, as well as in Suriname.

But it turned out that the stratigraphy and sedimentology was much more complex, and is different for each basin, he said.

A fourth example is discoveries in Sub Saharan Africa where oil was expected, but gas was found. This is understood to include BP farming into Kosmos' acreage in North west Africa, and Total's offshore South Africa discovery.

To understand whether oil or gas is going to be expelled from a certain source rock needs a lot of petroleum systems understanding.

"It seems to me it demonstrates lots of reasons we don't understand petroleum systems properly," he said.

"We all started believing 3D seismic is all you need to explore. Maybe was true at one time –

But not as thing s got more difficult and complicated.

"The underpinning thing is about timing of maturation. We oversimplify by applying stretching models when there's no reason to, other than we don't really understand what's going on."

This is a report from the the Finding Petroleum in Sub Saharan Africa event - 24 May, 2019, London

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Note:

Some of the slides and videos from this event can be downloaded free from the Finding Petroleum website event page

www.findingpetroleum.com/event/49001.aspx

How source rock works

Julian Moore, technical director with Applied Petroleum Technology, gave an overview of the latest thinking in how to understand how source rocks works, and so whether you might end up with gas or oil. He showed how his company applies these methods to reservoirs in South Africa

Understanding source rock and petroleum systems "is probably the most difficult part of the exploration process," said Julian Moore, technical director with Applied Petroleum Technology.

The company evaluates source rocks around the world, and recently completed a source rock project for South African National Oil Company PetroSA, looking at block 9, the Outeniqua Basin.

Most geologists do not go any further than to get a sense of the "total organic content" of a section of source rock (the mass of organic material), or its "hydrogen index" (the density of hydrogen atoms in the rock compared to water). Few geologists think about the way that oil is expelled from source rock, and that it works, he said.

There have been a number of high profile recent discoveries in West and South Africa, where the oil company was reported to have been expecting oil but got gas. This can be an indication of why more consideration to the subject is worthwhile, he said.

How source rock works

A BP geochemist called Andrew Pepper did some studies in how source rock works in the 1990s, developing what he called the "Pepper expulsion model", Mr Moore said.

He developed a set of equations "Pepper and Corvi 1995". One measures the free hydrocarbons (the amount of hydrocarbon liberated from the kerogen) and the other measures the relative convertibility of the kerogen to oil or to gas.

With these two equations, you can estimate how much oil or gas might be expelled from the source rock.

One method of working out convertibility to oil compared to gas is to take a sample of kerogen, decompose it through pyrolysis (high temperatures), and then use gas chromatography, to find out how much of different hydrocarbon molecules you have. The longer hydrocarbon molecules are more likely to form oil. Andrew Pepper defined a factor "G" which measures the relative proportions of oil and gas generative kerogen.

But the studies showed a strong correlation between this "G" factor and the hydrogen Indicator. So if the kerogen has a hydrogen index up to a certain point it is likely to break down to gas, and with a higher hydrogen index above this point, it breaks down to oil. The hydrogen indicator can be measured directly with a neutron log.

Julian Moore, technical director with Applied Petroleum Technology

Some of the kerogen does not break down at all into oil or gas, and this is a major factor in your end results. This inert kerogen can actually absorb oil, so oil stays in the source rock until temperature rises to a point where it can crack to gas, he said.

Conversely, having lots of oil generative kerogen (a high hydrogen indicator) can overcome the "absorptive" nature of inert kerogen, and the oil will be released, he said.

Burial history

Another important part of source rock analysis is to model the basin, looking at its burial history, thermal history (temperatures the various components would have been under), the maturity history of source rocks, whether any expelled oil would have found its way to a trap.

There are a number of ways organic material can get buried – in lakes (lacustrine), river deltas, or deep sea.

Algae deposited in deep lakes tend to generate oil; lacustrine source rock in general can be quite variable. Source rock from marine plankton and bacterial remains can produce oil and gas; and terrestrial plant material decomposed by bacteria, tends to generate mostly gas. The Kimmeridge Clay, formed from marine algae with terrigenous (land derived) input, can give anything from low gas oil ratio oils all the way to gas condensates.

The inorganic material

Source rock usually comprises organic material (the kerogen) mixed together with inorganic clay. But it is not like a reservoir, where the organic material sits in pores within the inorganic material. The organic material itself is carrying the load of the rock above it. "That's not always been particularly well realised," he says.

Some geostatistical modelling by Chevron in 1995 estimated that if the rock would need to be at least 4-6 per cent organic content by weight to have a pathway for the organic content to flow out of the clay as it formed oil. Organic material is denser than the clay, so 3 per cent organic content by weight means about 6 per cent by volume – 4-6 per cent organic content is 8-12 per cent by volume.

As hydrocarbons are expelled, the porosity increases, so it becomes increasingly easy for hydrocarbons to find a way out of the rock.

You can have other facies interbedded in the source rock. For example the Eagleford Shale has limestone interbedded. If these facies absorb oil that gets expelled, the equations won't work.

The oil can also be stored in nearby inorganic rocks. In onshore US, there is big interest in "oil saturated non-source rock intervals," he said.

This can change the gas-oil ratio of the expelled hydrocarbons, because gas and oil can get absorbed in these facies in different results. It is possible for non-source rock interbeds to double the gas-oil ratio. If you don't know about these interbeds, it is impossible to calculate what you are going to get.

This is often not taken into consideration into basin modelling. It is worth being sceptical if you hear someone present estimates that a reservoir may contain billions of barrels of oil, based on basin modelling alone, without considering that much of it may still be retained in the source rock, he said.

None of this makes it easier to model petroleum systems, but it does demonstrate that this is more complicated than most people realise. People typically don't even think about phase prediction (whether you get oil or gas), "let alone get it right".

Structures

Another factor in whether you end up with oil or gas is the shape, leakiness and pressure of the reservoir structure, he said.

If the pressure is high enough, gas will be in solution with the oil. At a lower pressure – below the bubble point – gas will come out of the oil and sit above it.

If the seal is tight, the reservoir will fill will gas, and oil will be pushed out of the trap beneath the spill point. But if the seal is weaker, it may allow the gas to leak, and hold the oil, so you get a reservoir full of oil.

For example, the Clare field in the North Sea leaks gas still today. "If it had a better seal t would have been a very large gas field," he said.

The shape of the reservoir is a factor. If it has a low relief structure (for example, a height of under 3000m), it is easier for gas to fill the reservoir. A higher relief will probably allow more room for oil.

We can say that for a higher pressure reservoir, whether you get oil or gas will depend on the source rock properties, but for a lower pressure reservoir, whether you get oil or gas may depend more on the geometry rather than the nature or maturity of the source rock.

This is also something very few people think about, he said.

South Africa

Mr Moore's company, APT, was asked to do some analysis for South African National Oil Company PetroSA, looking at source rock for the Outeniqua basin of South Africa. Total recently made a discovery of gas condensate here, and there were rumours that it had expected to find oil.

The region has a mixture of oil and gas fields, but dominantly gas.

The region has a wide range of source rocks, including lacustrine (lake formed) source rock, which is "probably quite oil prone", and a number of different marine source rocks.

It is quite hard to get data about what is being produced from different wells, because South Africa does a lot of gas-to-liquids chemical processing, and so sometimes reports gas production in terms of liquids, he said.

A well close to the Total well had a gas oil ratio of 18,000, so nearly completely gas. "On that basis the basin next door may be quite gassy," he said.

The oil that was produced from the Total well had an API (density) between 38 and 40, which is "not what you expect from marine source rock." The higher the API, the lower the density. By comparison, water has an API of 10.

Gas condensates and lighter (shorter hydrocarbon chain) oils have a higher API. In the North Sea, most oils have an API between 28 and 35.

Mr Moore took a selection of cores from South African wells in January 2019 and sent them to his company's lab in Norway. It did pyrolysis gas chromatography on a selection of the samples. It generates a range of TOC data.

The analysis shows "Something intrinsically more gas prone," he said – and the younger source rocks are typically more gas prone than the older ones. "We're still working through this data."

But altogether, Mr Moore would guess the Outeniqua basin "would have been fairly gas rich".

"It may prove to be more oily, I don't know."

Kerogen causing fractures

One audience member asked about a theory that when kerogen matures, it increases in volume, which increases the pressure, and creates a microfracture network. He asked if it is still a valid theory.

"I think it is still valid," he replied. "You do often see overpressure in source rock."

Although if you have reservoir rock below the source rock, you can release some of the pressure down into that reservoir rock. "The level of overpressure will be moderated by the ability to bleed pressure off. "If source rock is in the middle of a kilometre of shale, the ability to bleed off pressure will be less."

It would be very hard to quantify the volume increase with maturation, he said.

Analysing fluids

Mr Moore was asked how much you can learn about the source rock just from looking at the produced / sampled fluids – if you don't have a source rock sample.

"Things like API do give you an indication of the type of source rock," he replied. But "It's always difficult, when we've never penetrated the source rock.

"You [just] use as much data as you can."

Is there a giant oil field offshore Guinea?

Nick Cameron of First Exchange Corporation believes there are strong indications for giant oilfield potential in offshore Guinea / Guinea Bissau, based on geological interpretation and basin modelling backed up by analysis ofTDI-Brooks piston core samples.

Nick Cameron, chief geologist, First Exchange Corporation, a research organisation linked to Fortesa Corporation, an E&P company active in Senegal argued, using the results of piston core samples collected by geochemical exploration specialist TDI-Brooks from offshore Guinea Bissau, that an entirely new oil play existed there and across the border into western Guinea.

"Geological and basin modelling evidence, together the biomarkers from a seep recently discovered by Petroguin in Guineas-Bissau, reveals an active and regionally distributed, older Jurassic source," he said. "This source was previously unknown."

"That's quite a big statement in an area where no-one has seen any particular hydrocarbon sources," he acknowledged.

First Exchange is linked to Fortesa Corporation, an E&P company long active in Senegal.

Guinea and Guinea Bissau are neighbouring countries, south of Mauritania, Senegal and The Gambia. They are conjugate (formerly joined to) to Suriname and Guyana in South America where in the latter country there have been continuing giant oil discoveries in the last 5 years.

Giant sized gas fields have been discovered in countries close to Guinea / Guinea Bissau – including Tortue (offshore Mauritania) and Yakaar (Senegal). Oil has been discovered in the region – the SNE oil field offshore Senegal (Cairn Energy/ Woodside) and Sinapa offshore Premier Oil (Guinea Bissau).

The only hydrocarbon production so far between Côte D'Ivoire and Morocco is from Fortesa's fields in the Gadiaga area onshore Senegal, Mr Cameron said.

Jurassic source rocks have been known for many years further north, but previously no firm evidence for their presence was found this far south in Africa. However, they were known from the conjugate margin in Guyana and Suriname and oils in both these countries have been typed to these sources. This hard evidence he claimed provides powerful support for the validity of the present work.

Geology

Mr Cameron's geological work process was first to look at the geological settings, then review the basin modelling results and finally consider the evidence of the geochemical and

Nick Cameron, chief geologist, First Exchange Corporation,

piston core sample hard data.

The modelling was based on "pseudowells " positioned using TGS 2012 seismic and earlier Fortesa-Spectrum seismic.

TDI-Brooks subsequently made their 2001 piston core survey results from Guinea-Bissau available and these were then used to check and amplify the earlier results.

Mr. Cameron noted that this integration was a tense time, but the results were found to perfectly match the basin modelling predictions with a number of "high confidence hydrocarbon hits emerging in a previously non-prospective region" he said.

There were known mid-Cretaceous source rocks in shallow areas across the southern Guinea Marginal Plateau, but these were not buried deep enough to produce oil. The new Jurassic source, whose provisional age is placed at 169 My, however is sufficiently deeply buried to lie within the Oil Window and further west in the Gas Window he said.

"No-one's found any thick, mature source rocks in the Sinapa area, though rich, but still not fully mature sources are developed in the Turonian and Cenomanian" he said. A sample of Sinapa oil has been sent to GeoMark for analysis and it will be interesting to see if it has an Albian (107 My to 113 My) and/or Jurassic signature (the results are now available).

An oil sample from the Chinguetti oilfield (off Mauritania, discovered by Woodside Petroleum in 2001) has also been sent to GeoMark (the results are also now available), He noted that the source was traditionally regarded as Turonian or Cenomanian in age, but a Jurassic contribution to the oil is now predicted.

In terms of the reservoir, there are "huge closures above the mature Jurassic source". These closures are related to the Equatorial Atlantic break up unconformity which he places at 107 Ma. Carbonates are the primary objective in the southern Guinea Marginal Plateau with sandstone present further north.

Spectrum – looking for Gambia source rocks on seismic

Seismic company Spectrum is developing ways to identify source rocks on seismic data, experimenting on data for Namibia, The Gambia and Guinea Bissau

Seismic company Spectrum is developing methods to identify source rock from seismic data, experimenting on data for Namibia, the Gambia and Guinea Bissau.

There are features in the seismic response which are known to be possible indications of source rock. This can include lower amplitude reflections, low frequency, and opaque sections. This can be described as the "seismic character", explained Karyna Rodriguez, VP geosciences with Spectrum.

Karyna Rodriguez, VP geosciences with Spectrum

The first step of the work is to try to understand the region, including the paleogeography (historical geography) and regional plate reconstructions, to see if it can provide a sense of what source rocks it should expect. The second step is to look for seismic character which may indicate source rock.

The third step is to look for other evidence of a petroleum system, such as fluid pipes (carrying fluid from where it is generated to a reservoir), 'direct hydrocarbon indicators' (such as flat spots in the seismic), clusters of slicks at the surface, or evidence from cores which proves organic material, she said.

Spectrum's work builds on a paper published by Statoil employees in 2011, about ways to identify source rocks from seismic data. Statoil studied seismic and well data covering the North Sea Kimmeridge Clay source rock.

They found that seismic velocity and density will decrease and result in an overall decrease in acoustic impedance at the top of the candidate source rock interval.

They also found that there can be a higher horizontal velocity for source rock because there can be organic minerals aligned in a horizontal direction. This will affect the amplitude depending on the angle the seismic signal hits the source rock layer (which is linked to the offset). This results in an AVO Type IV anomaly.

They also found a relationship between amplitude of the reflected seismic and total organic content.

Namibia

Spectrum used Namibia, on the West Coast of Africa, to experiment with its source rock characterisation methodology, because it knows where the source rocks actually are. There are 12 wells which have encountered proven world class source rock. The region is a very active area for exploration activity, with Tullow entering the region in May 2019.

The paleo geographic reconstruction shows that there was a closed seaway at the time Africa was joined to South America. A closed seaway could be good for collecting organic material, she said.

There is Aptian source rock (120 million years ago, early Cretaceous) which is known to be important in petroleum systems off the West coast of Africa. It has been found in wells both onshore and offshore.

The seismic shows the source rock character, up to 200m thick, with low amplitude, low frequency seismic character.

To assess the reflection angles, you need to be able to do "angle stacks" – stacking seismic data which has the same angle. For this to work, the seismic needs to be matched in amplitude, time shifted, and matched in frequency and phase. This probably means you need either modern or re-processed seismic data.

One essential factor is to have modern or re-processed seismic data, she said. It is like turning a light on, she said.

Spectrum Attendees

Spectrum's analysis of Namibia shows the Aptian source rock layer with varying thickness, thinning to nothing then thickening again.

You can see the seismic velocity decreasing at the top of the source rock, showing as a decrease in acoustic impedance, and the seismic velocity increase again below it, with an increase in acoustic impedance. "Every single well in Namibia had the same," she said.

The source rock also showed a reduction in seismic amplitude with increased offset angles, a clear amplitude vs offset anomaly, as described above.

Another identification factor seen was that the seismic frequency was attenuated through the source rock section.

Spectrum also looked for slicks in the region from satellite imagery, in a research project conducted together with Airbus, which provided satellite imagery. The slicks correlated with the Aptian source rocks were on the seismic, she said. "It makes sense for hydrocarbons to be seeping at that place."

It was possible to see a track of hydrocarbon coming up through the subsurface on the seismic.

"That is, from start to finish, how we feel we have de-risked source rock in Namibia," she said.

The Gambia

In The Gambia, there are plays similar to the SNE discovery offshore Senegal, and the "Tortue" discovery offshore Mauritania. But the question remains about how much source rock there is, she said.

Spectrum looked for areas of the seismic showing a decrease in seismic frequency and found three candidate source rocks. One of these also showed a decrease in acoustic impedance, an amplitude vs offset anomaly, and a decrease in amplitude with depth. "So a lot of characteristics that we're looking for."

Another one of the three also showed amplitude anomalies and very extensive basin floor fan shape. "So we have two potential source rocks. There is a lot of potential out there," she said.

Guinea Bissau

For Guinea Bissau, large structures can be seen on the seismic – the question is whether there is any source charging them.

Spectrum looked for Jurassic source rock in the deeper part of the basin. It could see an area with a change in acoustic impedance, a drop in seismic frequency, and what looks like an amplitude vs offset anomaly. So there may be a source rock charging the large structures.

Altogether, "we feel we have proven concept in Namibia, taken it to Guinea Bissau," she said. "We have also taken it to other areas – Brazil, Somalia, and Mozambique. We feel it is a great methodology to de-risk source rock."

David Bamford - explorers need to think about ESG now too

Oil and gas exploration is no longer just about finding oil – explorers need to consider environmental, social and governance (ESG) issues, such as who their discoveries will lead their company to be working with and whether or not that is acceptable, said David Bamford

The way companies are approaching environmental, social and governance (ESG) issues is changing – they are being treated "much more coherently and collectively," said David Bamford of Finding Petroleum. "Things that were treated separately are now treated together in one list."

Dr Bamford's background includes roles as head of BP's business in Nigeria and Angola, where he was involved in many discussions about corruption. Dr Bamford has also chaired Tullow Oil's remuneration committee, while serving as a director, where he was involved in many discussions about the relationship between CEO pay and average employee pay.

Virtually every company makes a statement about sustainability, the good things they are doing, their safety record, their executive remuneration, and their approach to corruption, he said. Companies are looking more closely at their CO2 and methane emissions.

They are considering questions like, if they drill a well in East Africa, what should the land look like after they have left the country. What is their impact on the local community? Also staff diversity is increasingly an issue, he said.

Companies are being asked to consider what level of political risks they are taking, including their taxation agreements with the local government.

The investment advisory firm AllianceBernstein did a review of environmental, social, and governance (ESG) issues for a number of industries- as well as oil, it looked at mining, retail, media and leisure. It is "essentially a check list," he said. "Companies like AllianceBernstein are encouraging investors to ask about these things collectively."

Some oil and gas engineers are being taken by surprise by the reach of ESG projects.

In one example, production engineers for an oil company working in West Africa was asked why their company was flaring five times more gas than neighbouring companies – based on a researcher analysing satellite data. The concern was more money being wasted (by flaring gas rather than selling it), rather than emissions.

In another example, an exploration manager proposed investing in offshore acreage of a national oil company which was known for being corrupt, and which had elections coming up in the country. The oil and gas terms were also thought to be unstable. The CEO thought investing in that country was a ludicrous idea, Mr Bamford said.

"20 years ago I was deeply involved in BP investing in Mozambique, Angola, Nigeria, nobody asked me questions like that," he said.

Also, "investors are moving from being willing to accept what is written in company annual reports – to wishing to audit these things," he said. "If you've been through being audited by Deloitte, it is a pretty detailed experience."

And, "If companies do not do this, do not respond to investors, they will disappear," he said.

Finding Petroleum in Sub Saharan Africa May 24, 2019, London, Attendees

Hugh Ebbutt, Director, A T Kearney

Rogers Beall, Executive Chairman, Africa Fortesa Corporation

Paul Murphy, Key Account Manager, Oil and Gas Division, Airbus Defence and Space

Geoffrey Boyd, Field Development Consultant, Antium FRONTFIELD

Julian Moore, Technical Director, APT UK

David Craik, Consultant, Atlaslocal

Sean Goodman, Geophysicist, Austin-Bridgeporth

David Sendra, Associate Consultant, BlackRockQI

Lionel Therond, Director, Blue Oak Advisory

Joe M Boztas, Director/Interpreter, Boz Seismic Services

Andrew Webb, Manager, Petroleum Reservoir and Economics, CGG

Jodie Hunt, Marketing Geologist, CGG

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Paul Wilson, Senior Explorationist, Glencore

Toya Latham, Analyst, GlobalData

Norman Hempstead, Director, Hempstead Geophysical Svcs

Nick Steel, Consultant, Independent

Rupert Simcox, Data Analyst, Lynx Information Systems

Duncan Macgregor, Consultant Geologist, MacGeology

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David Lawton, Chief Geoscientist, SLR Consulting Ltd

Karyna Rodriguez, Director of Geoscience, Spectrum

Tim Browne, Spectrum

Ian Setterfield, VP Sales, Spectrum Geo

Andy Harris, SpectrumGeo

Vladimir Ayeli, O&G Investment Analyst, VAnalytiQ

Alastair Bee, Westwood Global Energy

What did you enjoy most about the event?

Regional analysis of source rocks.

Networking.

Networking, and continuous learning through good presentations.

Excellent set of presentations - very informative. I particularly enjoyed Spectrum's presentation on the seismic expression and prediction of source rocks.
Richard Walker (Cornhill Economics)

David's insightful and relevant comments.

Networking, and continuous learning through good presentations.

Interesting how decisions are made based on best technology information.