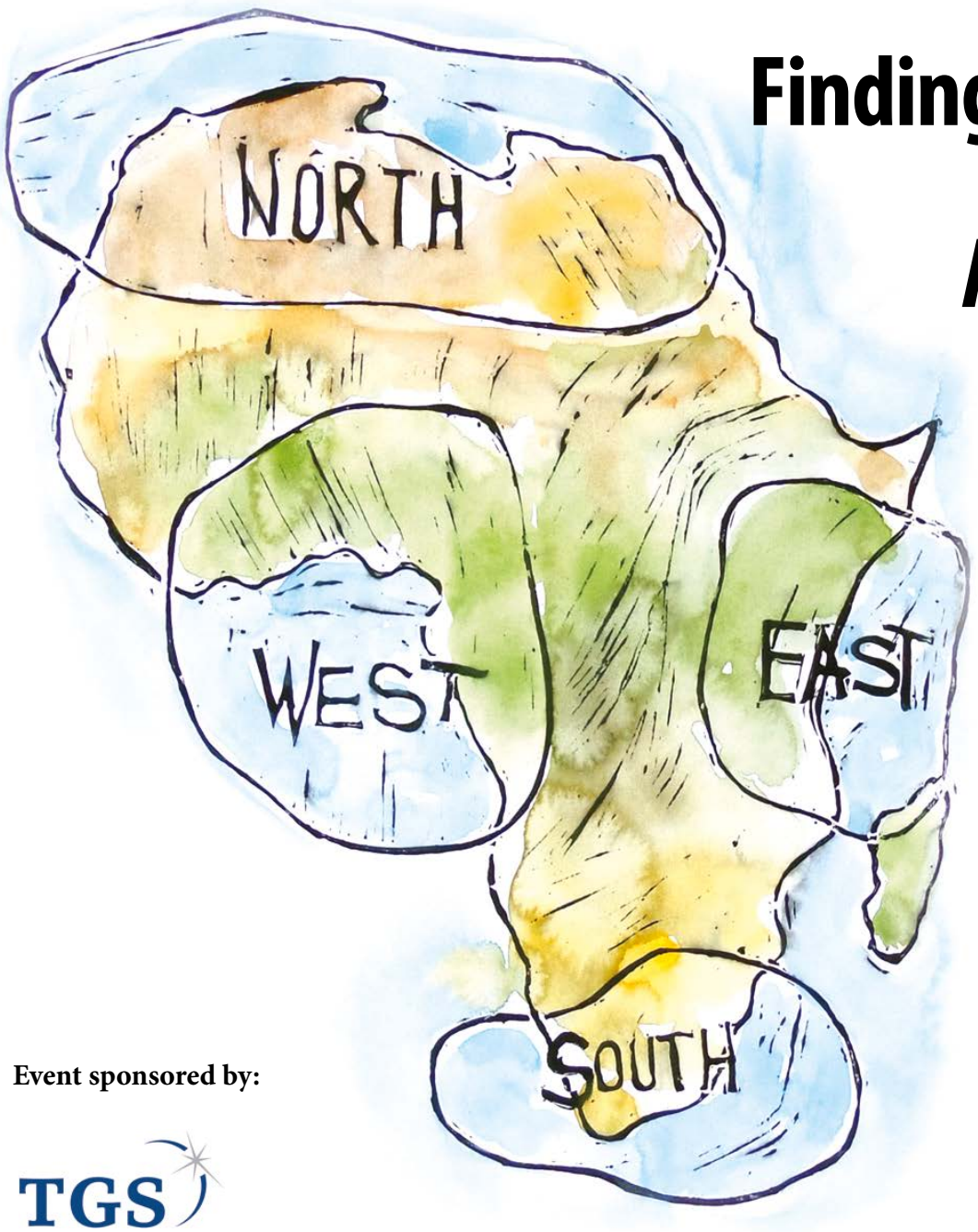
Finding Petroleum

- Why oil might be onshore East Africa
- Using satellite images to build structural maps
- South Africa's Outeniqua Basin
- Hydrocarbons offshore Madagascar
- Solo Oil in Tanzania
- Plate modelling for East Africa

Event Report, Finding East and Southern African Oil and Gas, Feb 23, 2017, London



Special report

Finding East and Southern African Oil and Gas

Feb 23, 2017, London

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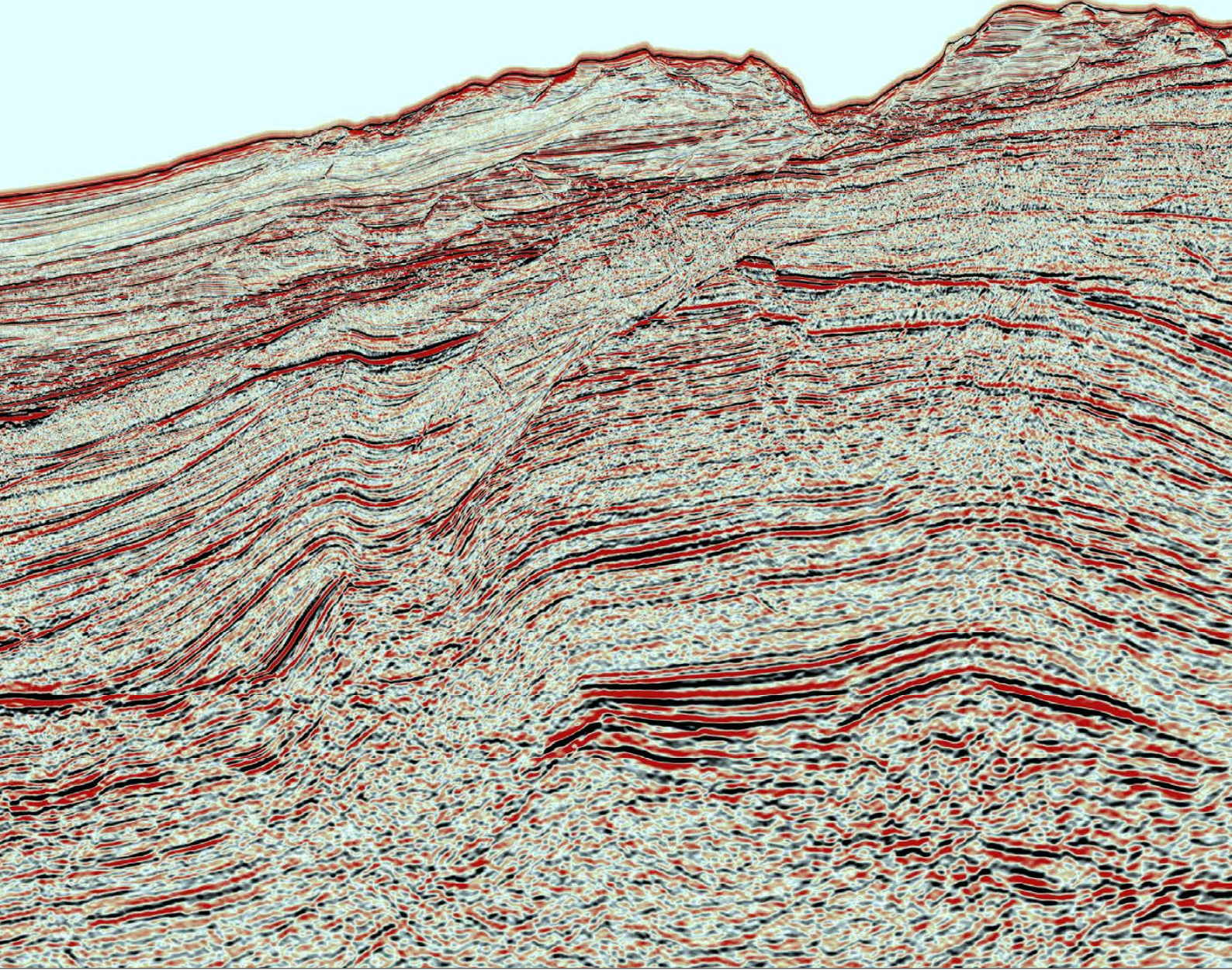
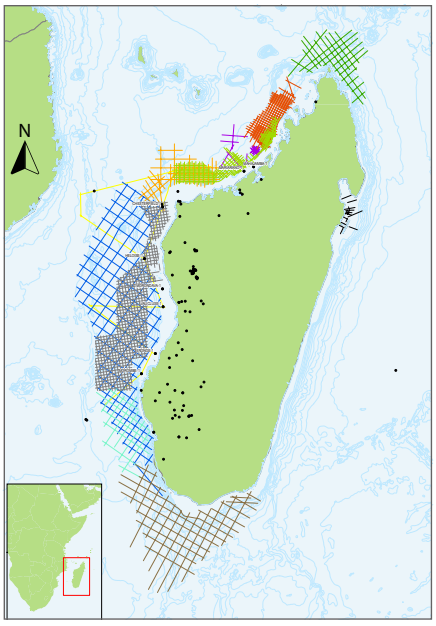


Madagascar

Data available

- Total - 49,000+ km 2D seismic data
  - » Ambilobe North (AMN14): 2,809 km
  - » Majunga Infill (MAJ13)*: 5,284 km
  - » West Morondava (MWM15)*: 13,134 km
  - » Morondava South Infill (MOS13)*: 1,889 km
  - » Cap St. Marie (CSM14): 5,979 km
  - » Vintage data reprocessed in 2014: 20,719km
- Gravity and magnetic data
- High quality digital log data for 116 wells

** in partnership with BGP*



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Finding East and Southern African Oil and Gas

Finding Petroleum held a forum in London on Feb 23 2017, looking at business opportunities finding oil and gas in East and Southern Africa, including experiences so far, using satellite images, offshore South Africa, Tanzania, Madagascar and understanding the plate modelling

Neil Ritson, chairman of Solo Oil, an investment company active in Tanzania, talked about his experiences in that country, in particular how he believes that the domestic market could be very interesting – because the energy consumption per capita is still very low, and the Tanzanian government is aiming to get electricity into all homes by 2025.

Neil Ritson

Ian Hutchinson, advisor – geodynamics and tectonics with Sasol E+P International, talked about the plate history of the continent, including how the Limpopo River would once have drained most of the continent (before the separation of South America to the west) – which is why the delta region of the Limpopo, in the South East, could be interesting for oil and gas.

Mike Rego of Triton Petroleum, formerly exploration director of Aminex, talked about his many years of work in Tanzania, and why there could be more opportunities available now which were not fully considered in the past.

Nick Tranter from TGS explained how his company sees the prospectivity in Madagascar, and Anongporn Intawong from Spectrum explained how her company sees the prospectivity in the Outeniqua Basin, offshore South Africa. Rowan Edwards from NPA Satellite Mapping explained how the company puts together structural and stratigraphic maps of the region, which can help understand the geology.

Note: all of the presentations and high resolution videos from this conference can be downloaded from the Finding Petroleum website at http://www.findingpetroleum.com/event/3025c.aspx, except that for the talk from Ian Hutchison of SASOL, where only an audio presentation is available.

This is a report from the Finding Petroleum conference "Finding East and Southern African Oil and Gas" held in London, in February 2017

Event website

www.findingpetroleum.com/event/3025c.aspx

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Cover art by Alexandra Mckenzie

Digital Energy Journal

www.d-e-j.com

Future Energy Publishing,
39-41 North Road,
London, N7 9DP, UK
www.fuenp.com

Mike Rego – oil might be onshore East Africa

Most of the exploration success so far in East Africa has been in deepwater – perhaps because it is easiest to explore there, said consultant Mike Rego, a former exploration director at Aminex, now MD at Triton Petroleum. But there are reasons why prospectivity might be better than expected onshore

So far, most of the exploration in East Africa has been deepwater, perhaps because it is easier to do seismic surveys there, said consultant Mike Rego, former exploration director at Aminex, now MD at Triton Petroleum, an oil and gas exploration company focussed on Africa.

Mike Rego

He was speaking at the Finding Petroleum forum in London on Feb 23, "Finding East & Southern African Oil &Gas."

But also, all of the discoveries so far have been gas, and oil has been something of a failure.

There are good reasons why there might be good prospectivity for oil onshore, and on the near shore, so it may be worth the effort of exploring, he said. However working onshore and on the nearshore would mean working in a different way to the past.

History

When understanding East Africa exploration, it may be helpful to look at past exploration in the region – which started in 1940s and 1950s with Shell and BP, active in Kenya and Tanzania, with many wells recording shows of oil and gas. Other companies were also active in Somalia and Madagascar and Mozambique

At the time, the oil companies were looking for structural features of substantial size bearing oil, but mere oil and gas shows from wells was not that exciting to them at the time.

Mr Rego showed a chart of wells drilled by different companies in different decades, showing that after this surge in activity in the 1940s – 1950s, there was not much activity until after around 2006, when exploration kicked off in most regions, except for Somalia (for security reasons).

The oil majors had basically lost interest by the 1980s and 1990s, he said. But they did make some potentially commercial gas discoveries, including Pande, Buzi and Temane onshore gas fields in Mozambique, Songo Songo and Mnazi Bay in Tanzania.

In Tanzania most of the recent activity was deepwater, with interest gaining momentum from around 2001, with minimal activity onshore and nearshore by comparison.

Before 2000, only 1 in 4 exploration wells in Tanzania were offshore. In Somalia only 1 in 13 were offshore.

There had been gas discoveries in Songo Songo and Mnazi Bay, but oil companies were not very interested in them mainly because of a lack of local markets, and often because there were no terms for gas in the Production Sharing Agreements signed with the host governments.

But from the 1990s onwards, governments were offering better terms for companies to come in and explore, thus appealing to smaller and less well established companies.

But smaller E+P companies tend to have limited cashflow from production so need to raise resources on stock markets and from investors, typically planning their finances around the absolute minimum needed to drill a well. Companies say "we're going to drill a well and in 3 months time we'll have x million barrels of oil."

But if the companies need to say, "we're going to shoot seismic, then shoot another phase of seismic, and then look for some drillable prospects", which is what finding oil in a frontier location is like, it doesn't sound so exciting, and so raising money is a lot harder.

Large companies were typically shooting onshore seismic in 10 x 10km reconnaissance grids, looking for large structural traps which would show on such a coarse seismic grid. As such, the seismic was not perceived to need as much analysis as for identifying detailed stratigraphic traps.

There are further problems with onshore and nearshore exploration, with shallow water, reefs (some of which are submerged and uncharted), local fishermen, coastlines, islands and tight vessel turning circles complicating the survey. "When you have a company with a restricted budget these are major deterrents," Mr Rego said.

In the 2000s, better seismic data became publicly available, including high quality offshore 2D seismic showing potential in the deepwater. Additionally there was the first of a series of major African petroleum conferences in 2003 organised by the East African Community in Nairobi, that encouraged exchange of information in East Africa.

Deepwater vs nearshore

Deepwater looks attractive for seismic companies as well as explorers, with the logistics and management being easier than onshore and nearshore.

With onshore seismic you have to deal with complex environmental regulations, line permitting, clearance, and damages, hire a large local labour force and have huge camps and large support functions.

"With open deepwater you can go backwards and forwards to your heart's content. Except for piracy, there's not too many problems."

Companies also need to send a large amount of kit for onshore seismic surveys, which can be prohibitively expensive for a one-off project.

So altogether there was not much appeal for larger seismic companies to come onshore or nearshore.

But there are rewards for companies which persevere with it, he said.

When it comes to drilling, you can drill two onshore wells and seismic for the price of 1 deepwater well, if it is done wisely.

Seismic Imaging

During a previous career with Aminex PLC, where Mr Rego was employed from 1998 to 2014 ultimately as group exploration director, he oversaw a project in 2010 reprocessing legacy 2D seismic data from the offshore shelf environment.

The results were initially disappointing.

One seismic survey had a far offset of 3,000m (the longest distance between source and receiver). Most nearshore seismic shot along the African margin up to the 1990s had a far offset of 1200m to 1500m. But a long offset is needed for amplitude vs offset analysis.

This particular survey revealed strong multiple energy (where the seismic has been reflected more than once in its travel path) over the initial 2,000m of offset.

By removing the offsets less than 2,000m, and stacking the remaining data, a greatly improved image was obtained. "We saw things we knew were supposed to be there but we'd never been able to see before on the shallow seismic," he said.

For example, one profile from water depths of 35m, showed up the lateral equivalent of 500m deep sands which could be oil bearing, including with deepwater feeder channels.

Such features weren't drilled previously because as 'structural bumps' they were not big enough, or they did not show up on the seismic due to the multiple energy.

Of course if the vintage seismic only has a far offset of 1200 to 1400m, you can't remove the first 2,000m, so all the data will be probably riddled with multiple energy, he said.

Onshore there are similar problems, with companies typically shooting coarse 2D reconnaissance seismic grids of 10km square. Perhaps another company would do an infill grid, to give 5 x 5km grid of 2D lines. But that is still too coarse to show up a stratigraphic trap. This means that companies will only drill something which shows up as a "big enough bump."

Seismic challenges

Some of the legacy onshore seismic data has "fairly basic static control", and so needs to be corrected with LVLs ("low velocity layers", a near surface layer of rock which seismic moves through at a lower speed). Quite often the LVL data may be lost or incomplete, including basic topographic data such as elevations (mountains and hills), etc.

Mr Rego showed a published example of a seismic line shot in 2014 over Aminex's Ntorya gas discovery, using regular LVL calculations and detailed field tests to work out the optimum source parameters.

"It sounds obvious to do detailed parameter test at the start of a survey. But when small companies were on tight budgets and everything was based on the drilling results, you want to spend as little time as possible getting it right," he said.

Companies have to work out the best combination of explosives to use, and what depth, and how many holes.

Getting explosives to countries like Tanzania and Madagascar needs to be planned months in advance, including working out where to store them, and which quantities you need, to satisfy all the requirements and maximise versatility. If the supplies don't arrive you have to keep crew waiting. "It's another little problem that causes the cost to go up."

Shallow draft vessels can help with nearshore seismic surveying – the MV Geomariner, active offshore East Africa 2005-2006 is one such vessel, with a 1.5 to 2m draft, enabling it to traverse submerged reefs. Typically, modern seismic vessels have a 4.5 to 7m draft.

If you want seismic with offsets of over 3,000m in the shallow coastal waters of East Africa, then you probably need to consider having a separate streamer and source boat making multiple passes as a possible solution.

You also need to find a boat crew prepared to go to East Africa.

If you are shooting seismic in the 'transition zone' (shallow nearshore), you will probably want to consider recording with cables on the seafloor, which also puts the cost up.

One approach is to try to share the costs of surveying with other oil companies in adjacent acreage, or sharing mobilisation/demobilisation costs.

If there is old/legacy onshore seismic with poor low velocity layer surveys (LVLs), it may make sense to reshoot the LVL surveys along the old profile routes, for input to reprocessing of the old seismic. It is a low cost option which can help improve legacy data.

Oil onshore

The drilling results so far suggest that the source rocks are increasingly mature, as you approach the continent-ocean boundary.

There has been a successive progradation of the shoreline (with a river delta pushing the shoreline farther out to sea over time). So the deepwater gas discoveries could have analogues in older strata in the nearshore and onshore, but they haven't been found to date due to difficulties with seismic imaging.

Many wells from along the margin have shown traces of oil as well as condensates, and the condensates show evidence of being derived by evaporative fractionation from oil, leading to the question of where those oils ended up.

In September 2016 Mr Rego got together with a group of 5 colleagues, under the guise of the East Africa Oil Group (EAOG) to try to answer that very question.

Their work involves trying to get a more detailed understanding of the history of the regional plate tectonics, hard because some of the plates have changed shape, and no longer precisely fit together.

There have been few wells drilled onshore and nearshore which directly confirm the presence of source rocks by penetration.

Aminex's Ntorya-1 discovery and Dodsal's Mambakofi discovery have been declared as significant gas discoveries, indirectly proving the existence of source rocks, and in the case of Ntorya-1 at least, inferring the presence of oil-prone source rocks.

There is clearly oil present along the margins – there have been numerous and well catalogued reports of oil seeps and tar balls.

Recently there has been a lot of effort by host governments and seismic contractors to promote deepwater and so-called ultra-deepwater, rather than nearshore, Mr Rego said.

But no-one can be confident of source rock presence or potential eastward of the Davie Fracture Zone (DFZ), or overlying transitional or oceanic crust (uppermost layer of the oceanic portion of a tectonic plate) to justify low risk deepwater drilling.

Many wells drilled in the 1950s to 1970s were classified as 'dry holes' even though they may have recorded oil or gas shows, simply because they weren't regarded as significant at the time. For dry wells today, a report that 'oil has been encountered', may imply anything from weak fluorescence on a set of cuttings to flowing oil.

Source rock

There is evidence for at least 2 different oil families along the coastal margin, coming from Permian- Triassic source rocks (Karoo), and from middle Jurassic. There is no firm evidence to date for a Cretaceous source, and only limited evidence for a potential Tertiary source.

The Mandawa Basin of Tanzania has up to 15,000 feet of Permian shales, with published data suggesting meaningful source rock potential. With such a thick shale, there should also be significant potential for shale oil and shale gas.

Analysis of source rock maturation suggests that virtually all Permo-Trias and Lower-Middle Jurassic source rocks will have been depleted by late Cretaceous, suggesting that most hydrocarbons found so far have likely migrated from trap to trap over time.

To understand trap prospectivity in more detail, a better understanding of the basin architecture is required, including better seismic imaging below 2000m, unfortunately the zone where most onshore and nearshore seismic is fairly ambiguous.

Summary

In summary one can say that the same source rocks that have provided all the deepwater gas are present in the nearshore and onshore, yet the nearshore and onshore is 'desperately unexplored', despite the potential for liquids at the basin margins, Mr Rego said.

To improve the chances of success, it is important to reduce the costs of acquiring seismic, and make better use of legacy data, as well as to form consortiums of explorers to share data and logistics costs wherever possible.

More flexible support from the local government would help, such as longer license periods from the standard terms to reduce pressure if a certain type of specialist seismic crew is not available within a suitable timeframe at reasonable cost, or adverse weather conditions delay data acquisition, and less onerous work commitments in particular environments to reflect the fact that some environments are harder and costlier to obtain data in than others.

"The East African margin does offer good opportunities for smaller independent explorers," he said.

NPA – satellite images used to build structural and stratigraphic map

NPA Satellite Mapping, part of CGG, is putting together structural and stratigraphic maps of different parts of the world, including the East African Rift System, derived from satellite images

NPA Satellite Mapping is putting together geological maps of different parts of the world, including East Africa, based on satellite images. Project geologist Rowan Edwards explained how it works at our Finding Petroleum East Africa forum on Feb 23rd.

NPA is part of geoscience company CGG, and has activities in mining, environmental, and geothermal industry as well as oil and gas. In the oil and gas industry it works both offshore and onshore.

For the oil and gas industry it has a range of satellite maps at different scales, with a 1:1M scale plate map, a 1:200,000 basin map, a 1:50,000 block map, a 1:10,000 field map for fracture mapping.

It aims to find places where it can improve on the existing mapping.

For example it has made an updated map of Kurdistan, which can better show the boundaries between formations, and some detail in the structural interpretation.

Maps of Africa

The company has created contiguous structural and stratigraphic maps of East Africa, using 15m resolution from the Landsat 8 satellite images, and an SRTM (Shuttle Radar Topography Mission) digital elevation model with 30m resolution.

It put together over 200 geological maps from 9 countries, to try to define the stratigraphic boundaries. All the information was put into a database, with a common stratigraphic template for all of the countries, and all of the structure and stratigraphy attributed, and consistent timings for the faults.

By using different band combinations the colour on the Landsat images provided information about the vegetation and volcanic sediment, and different types of basement. Images from the SRTM were also used here.

Rowan Edwards

The idea is that you start by putting together a structural framework, putting in the major features, then develop an overall structural interpretation. Then you can put in information about the stratigraphy behind it, with information about secondary lithologies, timings and faults. The map is generated from a database, so the information can be viewed in different ways.

There is a 'summary lithology' map, which shows extrusive volcanics (where magma flows out to the earth's surface in a volcano), and intrusive volcanics (where magma flows into the earth's crust).

The SRTM images can be used to develop drainage network maps, showing how rivers flow through catchment areas, to or from basins. So it shows the flows of fluids and sediment from one point to another.

This can be used for useful analysis, such as the potential for quartz sand to develop in a certain point.

Maps of Africa are of mixed quality – there are good ones and less good ones, made by different people at different times.

The NPA maps aim to fill gaps between existing maps and give clarity across borders.

The map database can be queried, to develop custom maps, such as showing all normal faults, or faults with a certain stratigraphy above them, or all Jurassic sandstones with normal faults.

It helps map how the rock has moved over geological time, and put together play fairways with source rock, charge, trap and seal.

In East Africa, there have been many different phases of deformation at different times. It is important to have detailed timings in order to work out where faults developed and how.

There are several different basement terrains. Some deflect the stress, some have stress through them. Because rifts are inherently low stress environments (since the rock is rifting after all), the faults are mainly developing in pre-existing weaknesses.

The Albertine Graben is a fairly linear fault, running North East to South West, partly through the middle of Lake Albert.

The Chew Bahir Basin, in contrast, has a very different geometry, with right angled faults, with pre-existing basin weaknesses. There is quite a lot of deposition between the areas.

As normal faults form they start to link together as they grow, and the formation of linkages has a large influence on how the rift segments. If there are basement structures nearby, this will lead to different linkage structures.

To take one example from Lake Natron, on the border between Tanzania and Kenya, there are 'relay ramps' (a structure with overlapping fault segments), which mostly align with the areas where most of the sediment input is, within the basin.

If you overlay this with an interpretation of fluvial deposition (how you think sediment is deposited), and add on gravity, you can get a more involved picture. The gravity lows correspond with drainage and fluvial deposition areas.

"You start to build up this idea of where it's coming from, where it's going to, the fault timing involved, and how that develops over time," he said.

NPA is now developing a map of the Eastern Arm of the rift, at a 1:50,000 scale.

The work is becoming easier as satellite data gets cheaper, much of it available free.

CGG has also done some work combining satellite derived slicks with its seismic survey data. "It does work well in certain places," he said.

Spectrum – potential in South Africa's Outeniqua Basin

The Outeniqua Basin, offshore South Africa, could offer good exploration opportunities. Dr. Anongporn Intawong, geoscientist team leader with seismic company Spectrum, explained further

The Outeniqua Basin, offshore South Africa, is relatively unexplored, but could be worth a closer look, said Anongporn Intawong, geoscientist team leader with seismic company Spectrum, speaking at the Finding Petroleum forum in London on Feb 23rd, "Finding East & Southern African Oil & Gas."

Dr. Anongporn Intawong

The Outeniqua Basin is situated off the south coast of South Africa. This basin consists of the Bredasdorp, Pletmos, Gamtoos and Algoa sub-basins in shallow water and the Southern Outeniqua sub-basin which is the deep water extension of those shallow water sub-basins. The basin is bounded by the NE-SW trending Agulhas-Falkland Fracture Zone (AFFZ) which has been developed during the South Atlantic Break-up. The fracture zone runs from Durban (up the North East coastline of South Africa) to Argentina.

On the Seafloor and land elevations map here showing the South Atlantic Ocean. The South Atlantic was separated in Late Jurassic along the AFFZ. As you can see on the map here that the Outeniqua is a conjugate margin of the Falkland Plateau offshore Argentina in the south-western corner of the South American plate. There are recent giant oil discoveries in the North Falklands Basin by Premier Oil/Rockhopper, Sea lion and Isobel Elaine containing a billion barrel of recoverable oil reserves.

There are also several oil gas and condensate discoveries in shallow water since 1969 in the Outeniqua Basin, starting from gas and condensate discovery in GA-A-1 in Pletmos sub-basin. This is very interesting discovery, gas and condensate were encountered in syn-rift Early Cretaceous marine sandstone drape on pre-rift structural high and fractured pre-rift and sub-aerial quartzite Table Mountain formation.

Then it was followed by a number of large hydrocarbon discoveries in 1980s and 1990s. The biggest gas and condensate discovery to date is F-A in the Bredasdorp sub-basin, and Oribi and Sable are biggest oil discoveries so far and each contains 50 Million barrels of oil recoverable reserves.

There are three main source rocks in the basin, syn-rift Late Jurassic lacustrine mudstone, Hauterivian–Barremian restricted marine mudstone, and Aptian-Albian anoxic restricted marine mudstone. These source rocks are proven both in the North Falkland, Orange and Outeniqua Basins.

Plate evolution

To understand the petroleum system, you should start by looking at the plate evolution of the South Atlantic. Dr Intawong presented work by Gaina et al (2013), showing the Mid Jurassic (170Ma), with Gondwana breaking up, the separation of India and Madagascar from East Africa.

In the Hauterivian Barremian (130 Ma) you can see the South Atlantic sea floor opening up, and the beginning of the development of the Agulhas-Falkland fracture zone, with right-lateral strike-slip motion between Africa and South America.

By the Turonian – Coniacian (90 Ma) you can see the seafloor spreading propagating northwards, and then the South Atlantic sea connecting with the Central Atlantic, also connecting with a mid-oceanic ridge south of the Agulhas – Falkland Fracture Zone.

In the South Atlantic, the ridge jumped toward the African plate around 60 Ma transferred South American oceanic crust to the African plate. This ridge jump ended the activity of the long AFFZ.

Meanwhile, the structural architecture of the Cape Fold Belt, played a key role in the formation and architecture of the Outeniqua Basin. This was studied by a Basin Structure Group at the University of Leeds (UK).

Seismic processing

Spectrum has the right from PASA to re-process all 2D legacy dataset in offshore South Africa both east and west coasts, and Spectrum has started to re-process a large amount of this 2D legacy data in the Outeniqua Basin in 2015.

The first phase of re-processing finished in February 2017, the second phase will come in the second quarter of 2017.

The re-processed data will support AVO analysis.

Proven plays and remaining plays

In her talk, Ms Intawong presented the new re-processed seismic images showing proven plays which can be used as analogues for future exploration. The seismic sections shown during her talk demonstrate Early Cretaceous basin floor fan of Sable and Oribi fields in the Bredasdorp sub-basin and Early Cretaceous draped sands and pre-rift quartzite Table Mountain formation of the GA-A-1 field.

She also presented an undrilled Early Cretaceous basin floor fan and large roll-over structural trap seen on the new re-processed seismic in the Bredasdorp sub-basin, and location of the shallow pre-rift basement high for chasing fractured and sub-aerial quartzite Table Mountain Formation play in the Outeniqua Basin.

She presented new play concepts remain to be tested in the Outeniqua Basin, ranging from roll-over anticline structural play in a simple Jurassic- Early Cretaceous syn-rift half-graben located in shallow water of the basin to a very large basin floor fan and channel plays with high amplitude supported by 15 km flat spot and positive AVA in the deep water of the basin. This could be a future giant discovery waiting to be discovered in the Outeniqua Basin, she said.

South Africa plans to approve new petroleum laws in Mid-2017, which are more favourable to oil companies, she said.

(Note the talk contained a large amount of geological description which is hard to describe in a written report, but is available on online video together with slides).

TGS – hydrocarbons offshore Madagascar

Seismic company TGS has carried out an integrated interpretation study into the prospectivity offshore Madagascar, which is planning a licensing round towards the end of 2017

Seismic company TGS has completed a geophysical and geological evaluation of the hydrocarbon prospectivity of the entire western offshore margin of Madagascar; from the Cap St. Marie Basin in the south, to the Morondava and Majunga Basins on the west, and up to the Ambilobe Basin in the north. Nick Tranter of TGS presented the analysis at the Finding Petroleum forum in London on Feb 23rd, "Finding East & Southern African Oil &Gas."

Madagascar could be announcing a licensing round towards the end of 2017. The government has put through a Petroleum Act, which was going through parliament at the time of the conference (Feb 2017), he said.

The study was based on 49,000 line km of multi-client 2D seismic data, of which circa 60 per cent was acquired in 2013 and 2014, with the remaining vintage seismic had been reprocessed, and available to license now. Also reviewed as part of the study was regional gravity and magnetic data and data from 98 exploration wells, of which 8 are offshore.

Offshore there has been one gas discovery, decreed non-commercial, the Eponge-1 well in Southern Morondava, other wells have contained gas shows. The majority of offshore exploration occurred in the 1970s and 1980s, of this 4 of the wells incorrectly targeted volcanic mounds, with the operators believing these intrusives were actually 4 way dip closures or carbonate reefs. Therefore only 4 offshore wells have targeted valid petroleum plays.

"So it is truly a frontier area," Mr Tranter said.

The geological history of Madagascar is reasonably well known, with three major events having influenced the formation of the offshore basins in its present form: Early Jurassic rifting of Madagascar-India from Africa, Middle Jurassic to Aptian movement south along the DFZ transform and Aptian to Late Cretaceous rifting that resulted in the break-up of India and Seychelles from Madagascar. An important factor highlighted was the uplift of Madagascar to the east, which caused erosion of sediment westwards into the basins, causing the thick sediment accumulation.

Nick Tranter

An offshore petroleum system was discussed in detail during the talk by Mr Tranter, which can be viewed online. Reservoirs and seals can be found at various ages, Permo-Triassic, Jurassic, Cretaceous and Tertiary, all identified by seismic, well data and onshore analogues.

The seismic sections shown during the talk display complex structural geology, with a variety of trap types present, ranging from; rotated fault blocks, three and four-way dip closures, salt related structures, pinchouts, drapes and even intrusion related closures related to the Marion hotspot.

Source rocks are probably the main risk offshore Madagascar, he said.

The Lower Triassic Sakamena lacustrine shales are proven onshore, having charged the Tsimiroro and Bemolanga fields in Madagascar with heavy oil, and the Mid-Jurassic shales, a proven source in East Africa have been identified.

Historically the main concern is the maturity of these source rocks. If present, they can be buried very deep and will be over mature. Basin modelling performed by TGS did show in some areas the Jurassic source expelling oil after trap formation.

A relatively new concept for the region discussed by Mr Tranter, is a source rock interval in the Early Cretaceous. He explained that "two onshore wells in the Morondava Basin, the Saronanala-1 and Serinam-1, encountered shales with high TOC levels, up to 7.7%, in a section from Cenomanian to Kimmeridgian. These organic-rich shales were deposited before Madagascar was uplifted in a restricted marine environment between the paleo-shelf and the DFZ which acted as a barrier and creating anoxic conditions in the basin. "

When modelled in the Morondava, this Early Cretaceous source showed expulsion of oil during and after trap formation.

Mr Tranter's talk included interesting seismic lines, detailed basin modelling and thorough descriptions of the hydrocarbon potential for each of the 4 offshore basins, opening up new ideas and possibilities for the region.

Both the slides and video for this talk are available on the Finding Petroleum website

Solo Oil in Tanzania

Solo Oil, a small investment company which takes an active involvement in the projects it invests in, sees that there could be great potential in Tanzania. Chairman Neil Ritson explained

Solo Oil, a UK Alternative Investment Market (AIM) listed investment company, has put most of its focus in East Africa over the last 10 years.

Altogether, Tanzania is a "near shore and an onshore [gas] play, not in my mind a deep offshore play," said Chairman Neil Ritson, speaking at the Finding Petroleum forum in London on Feb 23rd, "Finding East & Southern African Oil &Gas."

"There is also a possibility of an oil play."

Onshore gas production in Tanzania offers a major "first mover cost advantage," in that the first companies to enter the country may be able to do it at lower cost, he said.

Solo Oil looks at many different opportunities, and selects a very small number. It does not operate directly, but works closely with the operators.

"We are not a passive investor at all," Mr Ritson said. "We roll up our sleeves and interpret seismic and debate about whatever is going on. The aim of the exercise is to get us into early opportunities which are being overlooked, prove them and then move on."

Solo Oil was also the first technical partner in the Horse Hill project, potentially producing oil near Gatwick Airport, London. In the test well, "the flow rates were very exciting for the future of that particular venture," he said.

The regional picture

East Africa does seem to have something binding it together, both politically and geologically.

The term "East Africa" has various definitions, sometimes including the Horn of Africa (North East Somalia), sometimes including the offshore islands (Madagascar).

There is an important political binding force called the East African Community, which includes Burundi, Kenya, Rwanda, South Sudan, Tanzania, and Uganda.

Some of this union dates back to 1917, when there was a trading alliance between Uganda, Kenya and Tanzania, followed by a more formal alliance in the post war years. There was another union in 1967 after independence from colonialization.

Today, there is a customs union, a judicial system and a legislative body forming to cover the community. So the region is coming together.

As a geologist and oil entrepreneur, you get interested in 100 million years ago, and the past 100 years, and often the last 10 years, he said.

Tanzania is the most populous state, the largest state, and it has some of the largest cities in the East African Community. It is in the middle from a per capita GDP.

Comparison with Trinidad

It is interesting to compare Tanzania with Trinidad, the two countries where Mr Ritson works most of the time (he is also chairman of an oil company active in Trinidad called LGO Energy).

Trinidad has been developing oil for over 100 years and has a well-developed hydrocarbon economy. It could be described as overly dependent on hydrocarbons. There is a higher per capita GDP.

In Tanzania, in contrast, all of the discoveries were made in the past 10 years, and it is a developing hydrocarbon economy.

There is a middle class developing in Trinidad. Tanzania has much greater participation in the labour force, particularly women.

With life expectancy, which could be seen as a surrogate for quality of the health system, Tanzania has some way to go to catch up with Trinidad.

However, both Tanzania and Trinidad are well into the cellular age, as you can see from the penetration of cell phones and internet connection.

But perhaps the most interesting numbers, from an oil company's perspective, is the energy supply per capita – which is 30 times higher in Trinidad than Tanzania.

Neil Ritson

"This is what is driving our interest as an oil and gas company in Tanzania," he said. "That's the gap that can be made up by the investments that we're making."

It is estimated that probably less than 40 per cent of people in Tanzania have electricity, compared to 96 per cent in Trinidad.

Gas market

Across the whole of Africa, there is about 20 billion cubic feet (BCF) a day of gas production and about 10 BCF / day consumed, compared to about 7.5 BCF a day of gas consumed in the UK and about 3.4 BCF / day produced.

The African consumption is set to grow radically over the next 20-30 years.

In Sub Saharan Africa alone, natural gas demand is projected to be 18 BCF a day by 2030, 31 by 2040 and 52 by 2050.

Tanzania has political will to get electricity into all homes by 2025, which will lead to more demand for gas. "That is going to be a very difficult objective to meet. But it's the right kind of aspiration."

Getting gas to market

Solo Oil has a 7 per cent interest in the Kiliwani North well, which is just offshore Songa Songa Island, off the coast of Tanzania. The operator is Aminex. First production was in April 2016.

A new gas processing facility has been built on the island to handle the gas. The processing facility has surplus capacity, so further exploration and development is likely.

There is a gas sales agreement, providing a monthly income in US dollars. "That's a very significant step," he said. "That's commercial proof before we develop more gas supply in to this market."

"10 years ago, even 5 years ago, nobody in Tanzania could say that." Then you could produce gas, give to the government – and if you're lucky you might be paid in Tanzanian Shillings. Now we get paid on time in US dollars,"

It is one of three sources of gas supply to the Dar es Salaam region (the largest city in Tanzania with 4m population). However it can only provide 10 per cent of Tanzanian supply. "There's lots of opportunity for new fields to come on," he said.

"We're committed to do this, we're committed to that growth, and it's an exciting place to be. It has political and economic challenges, but we will be seeing some good news I am sure over the short term."

Looking more broadly, there has been 100 TCF of gas discovered offshore, including off the Mozambique coastline. The Tanzanian part of that is about 50 TCF.

The commercialisation process is ongoing, allowing gas to reach markets and stimulate demand, with a virtuous circle.

There are plans to export LNG by 2020, which is "fairly optimistic in my view," he said. But ultimately, the oil and gas majors will eventually need to liquefy gas, because the local markets are not large enough. "It is not all going to be absorbed by Tanzania." Some of the LNG may be sold to within the East African region.

The East African community overall is about 3-4 times as large as Tanzania.

There are many conversations about where gas pipelines might go in the region.

"Discovering gas is not that difficult, often it was discovered many years ago and then forgotten about," he said.

Dar es Salaam sits at the end of a 36 inch pipeline funded and built by China. It needs more distributing systems to connect the end of the pipeline to different industries.

"As this country continues to develop, there are tens of megawatts of gas power plants, this pipeline will become central to the commercialisation of the gas within the region," he said.

Working with Aminex

Solo Oil joined up with Aminex in 2010. Aminex was a 50 per cent partner in the Likonde-1 exploration well (drilled by Tullow Oil, the other 50 per cent partner), and Solo Oil farmed in to 12.5 per cent of Aminex's 50 per cent. The well is onshore, and was drilled in early 2010. It encountered thick sands with hydrocarbon shows. Drilling was terminated due to a high gas influx.

Getting additional seismic surveys proved tricky, the explorers are currently working with 2D. "It is difficult to do it and do it right, particularly on a tight budget," he said.

A current interesting project is the Ntorya 1 and 2 wells, on the onshore Ruvuma Basin of southern Tanzania, where Aminex has 75 per cent and Solo Oil has 25 per cent.

An appraisal well found over 30 metres of gas pay, with excellent porosities, significant gas influx, and pressures higher than predicted. There was also some black oil seen on the drilling cuttings.

The exploration objective was to look up dip, after a previous discovery in cretaceous sand in a channel system. The seismic appears to show an up-dip thickening of the reservoir interval, although it is hard to explore on 2D data.

The reservoir is bounded to the North, South, East and West, and there's scope for a large reservoir. A location has been planned for the Ntorya 3 well.

With 2D data, you have to drill in the places where 2 seismic lines intersect (and so you have a view of the subsurface in 3 dimensions), which does not provide you with many possible locations.

"The early advent of some 3D data is something I will be supporting," he said.

Plate modelling for East Africa

Ian Hutchinson, advisor – geodynamics and tectonics with Sasol E+P International, presented some perspectives on how the plates in East Africa have been put together

Plate modelling and understanding the paleogeography (geographical features at periods in the geological past) is fundamental to understanding the petroleum systems, said Ian Hutchinson, Advisor – geodynamics and tectonics with Sasol E+P International.

"You cannot get a handle on paleogeography if you don't have a handle on plate tectonics. The whole lot is fundamental."

SASOL is a large integrated chemical company, with most of its facilities in South Africa, where the company was founded. However it is expanding in the US and Europe. It is also a world leader in gas to liquids technology. The company holds 'significant acreage' in Mozambique (the country North East of South Africa) and has blocks offshore South Africa and in Gabon, in West Africa.

There have been studies of African plate tectonics for over 100 years. One of the first researchers was Alfred Wegener (1880 to 1930), who published work on the origin of the continents, including discussing their buoyancy and patterns of the coastlines, suggesting that the continents had originally been joined together. "He was largely ignored at the time because he was a meteorologist and a geographer, not a geologist," Mr Hutchinson said.

He was followed by Alex du Toit (1878 to 1948), who "recognised plate tectonics for what it was, and had the boldness to publish it," although his ideas were rejected at the time. He was a "fantastic field geologist who recognised the union of South America and Africa from looking at rocks both in Africa and South America, and by comparing scientific reports available from India and Australia," he said.

The leading scientists of the time were sceptical because they could not see what could power a system which could move continents apart. It took "such great scientific understanding as Arthur Holmes" (1890 to 1965), who "put his finger on nuclear decay occurring within the mantle driving convection systems at a scale sufficient to move the earth."

Continent boundaries

The Eastern continent boundary of Antarctica has not always been in the same place.

Its location in the geological past was studied by the Alfred Wegener institute based in Bremerhaven, Germany. On one 1970s expedition out at sea, it discovered a big sub-sea escarpment and sedimentary wedge (The Explora Escarpment and Wedge) were discovered, basically a 2000m subsea cliff.

The shape of the wedge and escarpment fits perfectly the notch in North East of South African coast (next to the Lebombo Mountains).

"This defines the tight fit of Antarctica and Africa," he said. "It is quite fundamental, it determines what the nature of the crust in Southern Mozambique is."

For getting an understanding of plate tectonics, Mr Hutchinson recommends the GPlates desktop software, developed by the University of Sydney and available for free download at www.gplates.org. "Also, it will generate nice images for your management presentations," he joked.

Using a published model from Seton et al. (2012), you can see how Africa and Antarctica fit together going back into the Jurassic, and how the gap developed through time, with Somalia and Mozambique oceans opening up at the same time.

Another good model has been developed by Colin Reeves, who runs a company called Earthworks. "It gives a very good starting block for looking at the very complex spreading history within the Indian Ocean."

Mr Hutchinson has been studying the fit between Antarctica and Africa since he was in university.

There is another publication from the Geological Survey of Finland, showing how Antarctica can fit with the Southern Mozambique basin.

At about 150 million years ago, there was rifting of Madagascar coming away from the Kenyan coast, and rifting between Antarctica and Africa, and later, a transform margin against the South African Coast.

There are Jurassic source rocks in East Africa, including in Madagascar, and also Maurice Ewing bank, offshore Falkland Islands today.

"Effectively we have our Jurassic source rocks forming in this early rift here off the African shores," he said.

However half of the Jurassic source rock which was once along the coast of Mozambique is now attached to the coast of Antarctica, he said.

Drainage

River draining patterns over Africa have changed over the geologic past.

The drainage area for the Limpopo River around the end of the Jurassic was probably starting in the Congo Basin (central Africa) – it could not drain to the West, because South America was there at that point. It would have been larger than the Niger River today. "It was a mighty river drawing sediment from the whole of central Africa," he said.

"The present day Limpopo is a small manifestation of the old Limpopo," he said. The Southern Mozambique Basin "is not recognised for what it is, an old Cretaceous age deltaic system."

Today, the Niger Delta has a very thick sedimentary sequence built out onto the oceanic crust, and the Nile is similar. The Limpopo delta is also similar, with a build-up of pro-grading sediment on Jurassic oceanic crust.

Also, at the beginning of the Cretaceous, this water would have flowed into restricted basins (because the East African oceans had not opened up). This environment is conducive to the deposition of source rock (half of which, is now in the Antarctic).

By the Middle Cretaceous, the Antarctic had been driven well away, so there were more like open marine conditions. South America is pulling away. But there was a 'footwall uplift' in West Africa which meant the river would continue draining to the South East in the Limpopo.

There was a sudden event in the Late Cretaceous, with a poorly understood mechanism, it could be some "early manifestation of East African rift tectonics", with an uplift along the Zimbabwe Kalahari-Line, which basically beheaded the Limpopo River, and cut off sediment supply to the delta, and created the draining system you see today.

The Kalahari sands cover a huge area of Southern Africa and are a product of an inland drainage system from this beheaded palaeo-Limpopo River.

Later on, about 20 million years ago, you see the Zambezi River taking over some of the waters which used to drain into the Limpopo, now draining in the Zambezi.

So the major supply of sediment switches to the Zambezi.

Then there was a very late uplift in the Pliocene which lifted the old delta of the Limpopo above sea level. So the present river is forced to cut through older sediments.

Using plate modelling, you can see the presence of oceanic crust.

It shows that you can't have Karoo source rocks because that Karoo is now in Antarctica.

"The form that we see here in southern Mozambique is paleo Limpopo delta and it formed entirely post rift. There's a Jurassic source play.

And those restricted marine conditions occurred up to the very earliest of Cretaceous at least," he said.

What did you enjoy most about the event?

Overall very good presentations, as usual! Particularly liked Neil Ritson's as he dangled some "upcoming good news" about their Tanzanian assets.

The quality and knowledge of the presenters, and the networking.
Mike Rego (Rego Exploration Limited)

Networking within an Africa-focussed group....

Talks network opportunities.
Paul Mullarkey (Auriga Energy)

Very good talks from Ian Hutchinson and Neil Ritson.

The talks and debate at coffee.
(Lukoil)

Several 'mind opening' talks, e.g. by Hutch.
Nick Cameron (GeoInsight Limited)

Regional overview.
David Craik (Atlaslocal)

Opportunity to network and listen to new ideas.

Range of talks.

Finding East and Southern African Oil and Gas
The Geological Society, London, Feb 23 2017 Attendee list

David Roberts, Consultant, 3-DMR

Christian Bukovics, Partner, Adamant Ventures

Alec Jones, Aker Solutions

Geoffrey Boyd, Field Development Consultant, Antium FRONTFIELD

David Craik, Consultant, Atlaslocal

Paul Mullarkey, Managing Director, Auriga Energy

Christian Richards, Sales Manager, AustinBridgeporth

Joe M Boztas, Director/Interpreter, Boz Seismic Services

Ken Agu, Executive Director, Bresson Energy Limited

Derric Richardson, Bridgeporth

Darren Jones, Geologist, British Geological Survey

Chris Matchette-Downes, MD & Owner, Caribex and MDOIL Limited

John Glass, Consultant Geologist, Cloverfield Consulting Ltd

John Cryan, Geophysicist, Consultant

Craig Lindsay, Director, Core Specialist Services Limited

Dan Kunkle, Director, Count Geophysics

David Boote, DBconsulting Ltd

David Jackson, Global Manager G&G New Ventures, Dolphin Geophysical

Ian Blakeley, Global Oil & Gas Analyst, Account Development Manager EAME, Drillinginfo

Emma Woodward, Regional Manager, West Africa, DrillingInfo

Telamon McCullough, Reservoir engineer, ENGIE

Roger Bignell, Geological Consultant, Fairway Exploration

Karl Jeffery, Editor, Finding Petroleum

Avinga Pallangyo, Conference Organiser, Finding Petroleum

Richard McIntyre, Sales Manager, Finding Petroleum

Mark Llamas, Managing Director A&D, FirstEnergy Capital LLP

Jeremy Berry, BD Director, GCA

Nick Cameron, Geological Advisor, GeoInsight Limited

James Gulland, Director, GeoPartners Ltd

Jim House, Director, GeoSeis Ltd

Waclaw Jakubowicz, Managing Director, Hampton Data Services

John Corr, Manager - Consultancy, Hannon Westwood

Jay R Blanc Selva, VP, HUawei

Lawrence Jackson, Senior Account Executive, IHS

Phil Carpenter, Business Development Manager, Ikon Science

Peter Dolan, Chairman, Ikon Science Limited

Patrick Lynch, Independent

Harry Kweku Harrison-Sumter, Senior Consultant - Africa, ITE Group PLC

John Griffith, Upstream Advisor, JJG Consulting International Ltd

Joe Staffurth, Director, JSI Services

Somar Abdullatif, Senior Geoscientist, Leinster Oil

Fergus Jenkins, COO, LGO Energy

David Peel, Technical Director, Lukoil

Anne-Mette Cheese, Exploration Geologist, Lukoil

Brian McCleery, Director, M2C Energy Advisers

Duncan Macgregor, Consultant Geologist, MacGeology

Nina Gray, Managing Director, Major, Lindsey & Africa

Mike Naylor, Director, MN Solutions (Cambridge) Ltd

James Andrew, Busines Development Mgr EAME, NEOS

Mike King, Oil & Gas Manager, NPA Satellite Mapping

Rowan Edwards, Project Geologist, NPA Satellite Mapping

Jodie Cocker, Remote Sensing Geologist, NPA Satellite Mapping

Mark Broadley, Senior Geologist, NPA-CGG

Helen Turnell, Principal Consultant, NR Global Consulting Ltd

Martine Davis, Business Development Manager, NVentures

Robert Parker, Consultant, Parker

Christian Fenwick, Director, Penarvon

Mike Rego, Independent Consultant, PetroMall Ltd

Henry Dodwell, Consultant, PetroVannin

Ewan Rossiter, Consultant Geoscientist, PetroVannin

Matt Tyrrell, Principal Geoscientist, PGS

Kevin Sylvester, Director, Pinnacle Energy Limited

Peter Elliott, Consultant, PVE Consulting Ltd

Josh King, Analyst, RAB Capital

Robert Snashall, Consultant, RGSConsult

Andreas Exarheas, Assistant Editor, Rigzone

Andrew Webb, Deputy General Manager, Robertson Limited

Martin Smith, Business Development Manager - Operations, RPS Energy

Gordon Taylor, Head of Subsurface, RPS Energy

Bimbola Kolawole, Business Development Manager, Rystad Energy AS

Kevin Dale, Exploration Advisor : New Ventures, Sasol E & P International

Ian Hutchinson, Advisor – Geodynamics and Tectonics. Business Development (Exploration), Sasol Petroleum International

David Webber, Seismic Operations Supervisor, Sceptre Oil & Gas

Terry Devine, Asset Development Manager, Schlumberger

Simon Gozzard, Exploration Geoscientist, Shell

Tom Martin, Director, Shikra Consulting

Alexander Chalke, Business Development Director, Simpson Booth

Neil Ritson, Chairman, Solo Oil

Gareth Morris, Account Manager, Spectrum

Anongporn Intawong, Geoscientist, Spectrum ASA

John Hall, Business Development Geophysicist, Spectrum Geo Limited

John Hall, Business Development Geophysicist, Spectrum Geo Limited

Nigel Flood, Multiclient Sales Manager, Spectrum Geo Ltd

Vibhusha Raj Sharma, StrategicFit

Kieran Aust, Business Dev. Mgr., Suez Oil & Gas Systems

Andrew Longman, Managing director, Terranes

Roel Dirkx, Interpretation geophysicist, TGS

Nick Tranter, Project Developer – Africa, Mediterranean and Middle East, TGS

Ben Sayers, Project Developer, TGS

Chris Anderson, Sales Director, TGS

Simon Bradbury, Chief Operating Officer, The Steam Oil Production Company Ltd

Nigel Quinton, Consultant, Tower Resources plc

Hugh Ebbutt, Independent, Upstream Adviser

John Wood, Geoscientist, Wood Geoscience Limited

Helen Ricketts, Business Development Manager, Wood Group Kenny

Alexander Burnett, SSA Data Analyst, Wood Mackenzie

Jake Berryman, Senior Geophysicist, WyeDean

multi-client seismic

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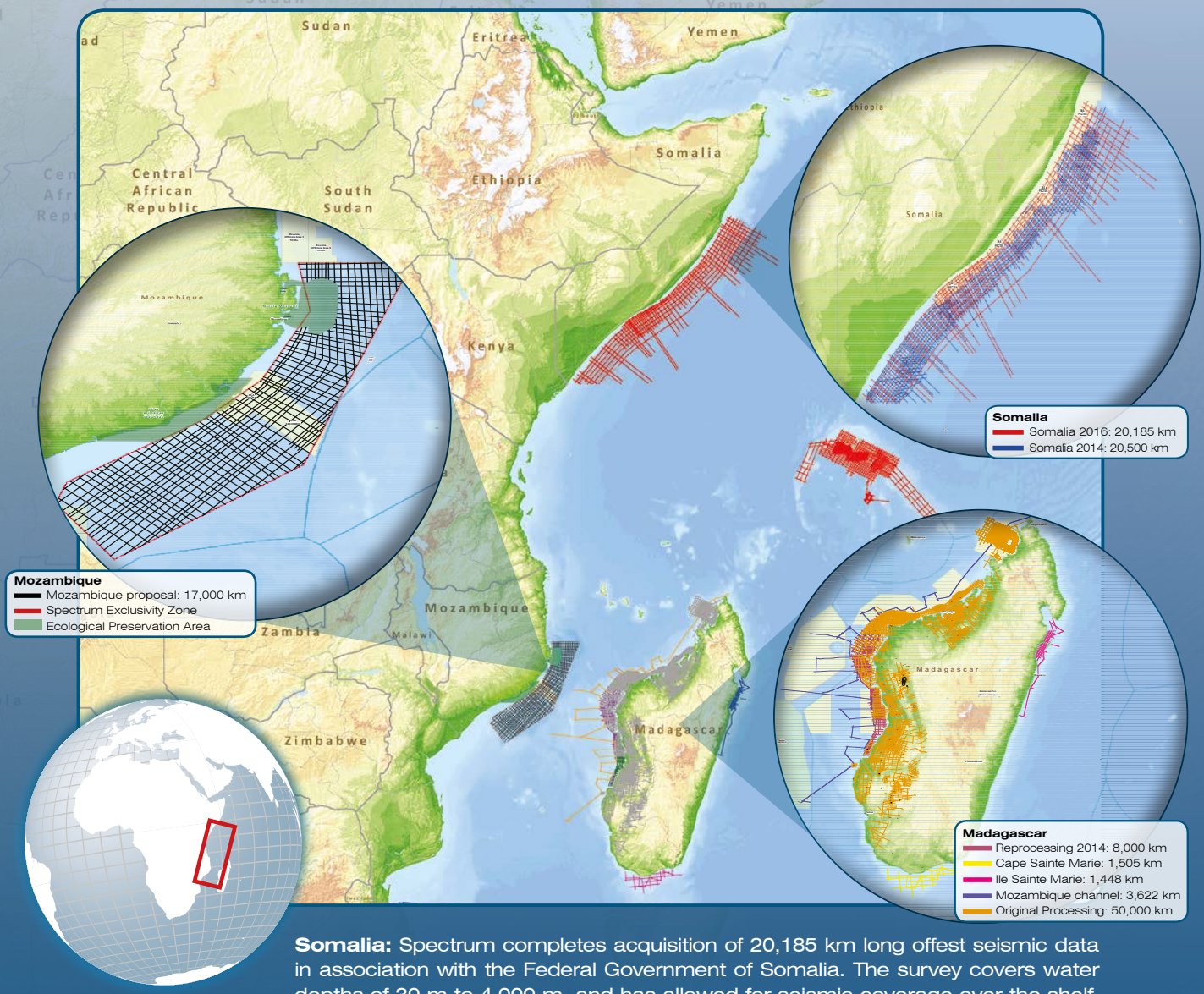
Offshore East Africa

Unlocking the Hydrocarbon Potential Offshore East Africa



Somalia: Spectrum completes acquisition of 20,185 km long offest seismic data in association with the Federal Government of Somalia. The survey covers water depths of 30 m to 4,000 m, and has allowed for seismic coverage over the shelf, slope and basin floor.

Mozambique: Spectrum has been selected to undertake a comprehensive long-offset Broadband 2D Multi-Client seismic survey. New seismic data will image the subsurface potential in the southern Rovuma Basin and the western flanks of the Kerimbas Graben, west of the Davie Fracture Zone, revealing the prospectivity in this region for the first time.

Madagascar: Spectrum has signed an agreement with the Madagascan agency OMNIS (Office des Mines Nationales et des Industries Stratégiques) granting the company exclusive brokerage rights to the vast majority of seismic data situated both offshore and onshore Madagascar totalling over 69,000 km.

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