Low frequency passive seismic has a special role to play in Africa. Karim Lassel, Business Development Director, Europe & Africa, Spectraseis, discusses

The challenges facing African oil & gas exploration

THE PAST DECADE has seen Africa enjoy an unprecedented boom in oil & gas investment, particularly in the Gulf of Guinea and in North Africa.

According to research conducted by industry consultancy, John S Herold, between 2002 and 2006, publicly-listed oil companies tripled their spending in Africa, a rate that was 20 per cent more than their spending across the world during the same period.

While the high profile fields off the coast of Angola and Nigeria have garnered considerable attention, equally important have been the onshore fields of North Africa.

For example, the Sirte Basin in Libya, much of which is onshore and which occupies a massive area of 230,000 sq km, has estimated proven oil reserves of 43.1bn barrels, ranking it the world's 13th largest petroleum province. And with Libya's reintroduction into the international community in 2003 and 2004, there has been a corresponding increase in foreign investment.

Another giant field is the Hassi Messaoud basin in the eastern part of Algeria which contains 70 per cent of the country's total proven reserves and covers an area of 2,000 sq km. And, despite the fact that Algeria has been producing oil since 1956, many industry analysts still consider the country to be under explored with significant potential for future hydrocarbon discoveries.

Finally in Egypt, most of the blocks under Ganoub El Wady Petroleum Holding in upper Egypt - corresponding to south of latitude 28° N - are vastly unexplored representing large areas of high potential and also high risk.

The same is true across the continent. Despite recent investment, the fact remains that Africa in general remains relatively under explored for hydrocarbons, even in established producing countries, such as Algeria, Libya and Nigeria.

According to Wood Mackenzie Consultants, the country of Libya, for example, remains 'highly unexplored' and has 'excellent' potential for more oil discoveries. This under exploration is mainly due to sanctions, to the lack of modern technology, and relatively strict fiscal terms on foreign oil companies.

The need for reduced risk

Such onshore fields and unexplored regions come with a series of unique challenges.

The sheer size and remoteness of some of the unexplored areas, their growing geological complexity, and the importance of reducing spiralling drilling costs, has underlined some of the limitations of relying solely on conventional seismic techniques.

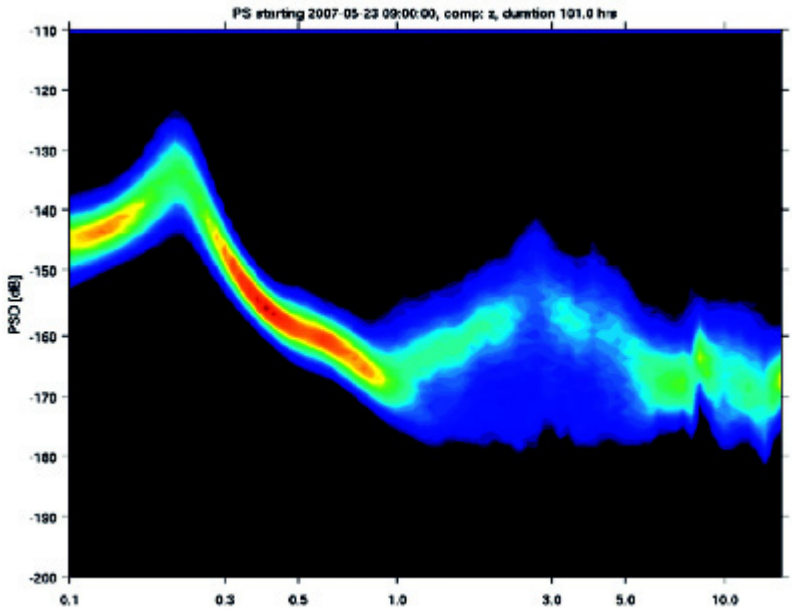

Figure 1: PSD plots

There are some areas, for example, where the density of wells is very low compared to the size of the area, indicating there might be potential for further E&P activities. Take Libya's Sirte Basin. The basin currently has only 3.3 wells per 100 sq km with recent estimates pointing to more potential from the basin with clastic reservoirs beneath the carbonate reservoirs in the central part of the basin.

> One challenge is that many onshore North African resource plays and prospects are to be found in environmentally fragile areas such a deserts

As the industry explores increasingly complex and remote reservoirs, some of the limitations to conventional seismic start to appear. In the Western hydrocarbon provinces of Libya, for example, many of the structural and stratigraphic traps have been surveyed. Operators are looking for methodologies that can detect not only structure but fluid content in geological settings.

With national oil companies in Africa having three to four times the lease acreage they had only five years ago, operators need to manage risk and ensure their investments are viable.

When moving into unexplored and under explored basins, operators need to optimise their well positions, have the best available information when making drilling decisions, and reduce the prohibitive costs of non-productive exploration surveys and dry wells. And the threats of dry wells remain common in Africa. In May last year, Swedish oil company **Lundin Petroleum**, encountered its second dry well in Muglad Basin in Block 5B, Sudan.

Another challenge is that many onshore North African resource plays and prospects are to be found in environmentally fragile areas - deserts, such as the Sahara or in the case of Libya, Roman ruins in some places. Apart from the poor seismic response that often comes from areas, such as deserts, they are also sensitive to infrastructure, people, and transportation procedures. Such environmental risks need to be addressed.

Another example of a sensitive area is the Northern parts of the Algerian deserts where the deserts meet the mountains and where most of the area is covered by forest. You could imagine the environmental outcry if there was a need to start cutting down trees

in a country that is 80 per cent desert.

There are local drivers as well. Operators working onshore often face issues with community activities, ethnic conflicts and regional territorial feuds. They also face relatively strict requirements to employ local personnel – even when the local expertise isn't always necessarily available. In countries, such as Nigeria, for example, there has been a growing focus on the domestication of seismic processing over the last few years.

Such growing challenges and potential reduction in margins have also seen a scaling back of some operators' activities in Africa. For example, independents, such as **Devon, Occidental** and **Woodside**, have all reduced their African activities, and Shell is currently going through a restructuring plan in Nigeria.

In such cases, a relatively light footprint and a requirement for not too many resources and personnel in exploration while, at the same time, the ability to generate new subsurface information, is essential.

The rise & progress of low frequency passive seismic

Fortunately, however, technology does not stand still. Recent innovations in extracting attributes from low frequency data are showing strong applicability for high-grading frontier areas and de-risking African exploration investments.

Low Frequency (LF) Passive Seismic produces spectral attributes of naturally occurring, low frequency (<10Hz) seismic wavefields.

A growing number of surveys over different oil and gas fields throughout the world have established the presence of spectral anomalies in the ambient seismic wave field with a high degree of correlation to the location of hydrocarbon reservoirs.

Anomalous energy in the power spectral density (PSD) plots from stations above a reservoir can be recognisable compared with the PSD curves generated with data from stations well away from hydrocarbon accumulations. Passive seismic surveys in prospective hydrocarbon regions add fluid content information to help prospect ranking and minimising E&P risk.

Figure 1 shows PSD plots. A marked energy anomaly is clearly visible. Seismometers collect data proportional to particle velocity, v. An appropriately defined integral under the PSD curve then will have units v2 which is proportional to energy in Joules.

In addition, the data from developed fields suggests that some of the low frequency signal energy, associated with producing hydrocarbon reservoirs, results from the dynamics of the production environment.

However, even in a production environment, it has been possible to identify low frequency hydrocarbon-related anomalies, which are distinct and often spectrally isolated from the anthropogenic broadband noise. Furthermore, in the absence of production activity, such as in frontier exploration settings, the identification of hydrocarbon reservoirs has subsequently been confirmed by drilling.

LFPS survey in Libya

Since 2003, we at Spectraseis have been commercialising this innovative technology to help operators more efficiently find and produce hydrocarbon reserves, as a complement to conventional surveying and seismic techniques. Today, Spectraseis counts PEMEX, Petrobras, Ecopetrol, StatoilHydro and a Saudi Aramco joint-venture among its customers and has recently completed a low frequency passive seismic land survey totaling over 300 km² in Libya.

E&P benefits for African operators

So what are the benefits to the operator engaged in oil & gas exploration onshore in Africa? And what is likely to be the future progress of what remains a relatively young technology?

For oil & gas exploration in Africa, LF passive seismic reduces risk in three key areas: managing costs, improving information, and alleviating HSE and environmental risks.

One of the single biggest challenges for E&P operators in Africa is to manage costs. Even when oil prices were high, the costs of exploring and producing oil & gas in Africa has been rising with often a shortage of experienced local engineers and geoscientists.

Furthermore, the advent of small and mid-sized oil companies into Africa – companies which lack the financial clout of the majors – has increased the focus on cost.

Traditional seismic and the vast areas to be covered has only increased the potential financial investment, with extensive infrastructure and resources required, such as large cable-based systems and electrical methods requiring external resources, such as explosives and vibrators.

Through LF passive seismic and the potential to economically image potential hydrocarbon reserves, operators can have increased confidence in their drilling decisions and save potentially billions of dollars, currently expended on non-productive exploration surveys and dry wells.

The second benefit of LF passive seismic is that it improves the value of conventional seismic data. With the industry running out of classical structural traps (as is the case in Libya, for example), the detection of more subtle traps and reservoir fluid content, which LF passive seismic enables, is more important than ever before. In this way, operators can compartmentalize large areas according to high potential and low potential and plan its E&P strategy accordingly.

Thirdly, LF passive seismic has a very light environmental footprint with no need for external sources, as is the case of conventional seismic. LF passive seismic can cover 400 to 500 km² in less than 30 days and conduct a full analysis of the data 90 days from then. The ability to generate data from some of the world's most remote locations in days and weeks rather than months and years as well as the subsequent reductions in cost is of particular value to the operator in Africa.

And such a light environmental footprint and ability to cover vast tracts is particularly useful in areas such as Egypt's oil and gas exploration areas, such as the Western and Eastern Deserts.

Finally, a light environmental footprint also means fewer HSE (Health, Safety, and Environment) implications. With fewer people, fewer heavy vehicles and less time in the field, there is reduced exposure and risks for the operator.

New developments in low frequency passive seismic

So what of the new developments in low frequency passive seismic?

New research into the statistical characteristics of low frequency seismic data is resulting in improved workflows that produce new statistical LF attributes and can be used to make probability estimates.

Spectraseis has greatly increased its stable of high quality sensors to enable more synchronous measurements for each survey and also provide the capacity to conduct multiple projects in different parts of the world.

Spectraseis is also developing a complete end-to-end solution for low frequency data from acquisition systems through to processing and interpretation, manifested through to advances in its processing and analysis software.

New features include; Field Office 1.1, an automated system which allows the acquiring and managing of field data to be quick and efficient. Field Office 1.1 is used by the field crew to acquire and provide early quality control over the LF passive seismic data and manages all type of acquisition media, including images and GPS before the data is transmitted to Spectraseis' processing and analysis centre; and RioViz, which processes the LF passive seismic data and allows for the viewing, analysing and interpretation of the new geophysical data set.

Spectraseis has been in regular discussions with operators in Libya, Algeria and Egypt.

The result is the transformation of raw low frequency field recordings into valuable information and the attribute profiles and maps operators require.

There is also much research, which continues to be done into identifying the underlying physical mechanisms behind the observed phenomenon of LF passive seismic. Studies and theory of anomalous seismic attenuation at low frequencies is a major target of the Spectraseis' and Swiss government supported research team at ETH Zurich, one of the top research institutions in the world and a partner of Spectraseis.

Additional ETH Zurich research programs include fluids saturated rock attenuation laboratory measurements at low frequencies and variable field arrays for wavefield decomposition and near surface velocity studies.

Spectraseis in Africa

Spectraseis has a growing presence in Africa and has conducted two surveys in Libya. This included a 'blind' pilot test on an active producing field where results could be validated against current field knowledge and calibrated with existing geoscientific information for application to other areas.

Measurement locations were identified with 1,000-m node spacing, portable broadband sensors were then buried in the sand and the data later downloaded. The average recording time for each sensor was 24 hours.

Data quality and consistency, quality control and organisation of the field data was all performed at the local level before transmission to Spectraseis' processing and analysis centre.

The second Libyan survey was a pilot exploration test over a new prospect with the objective being to identify probable hydrocarbon-bearing areas. In this case, access was difficult due to high dunes. The area of 230 sq km was completed with 50 per cent more data in 20 per cent less time than was originally planned.

In regard to other activities in Africa, Spectraseis has also been in regular discussions with operators in Libya, Algeria and Egypt. Spectraseis is due to initiate another land based survey in Egypt in February 2009.

A powerful tool

Today, LF passive seismic is a powerful de-risking tool with applications across the entire reservoir lifecycle, from license bidding, de-risking and prospect ranking through to appraisal, exploration, and development. There is much for operators in Africa to take note of. ■