Building on BP's large-scale OBC monitoring experience—The Clair and Chirag-Azeri projects

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From the very beginning of 4D seismic technology in the 1990s, BP has taken a great interest in testing and developing ocean-bottom cable (OBC) monitoring as an alternative to conventional streamer surveys. Today, permanent OBC or "life-of-field-seismic" (LoFS) systems, together with semipermanent OBC systems, are an important method to acquire high-quality, consistent, and potentially frequent 4D data in selected fields. They are believed to represent a cost-effective means to acquire 4D data at intervals of about one year or less and are considered a key step toward the goal of optimally managing reservoirs as part of the "digital oilfield" concept.

BP's first "proof-of-concept" trial with this technology was the North Sea Foinaven Active Reservoir Monitoring (FARM) system (1995–1998), and BP has now deployed the world's first three at-scale OBC monitoring systems (Figure 1).

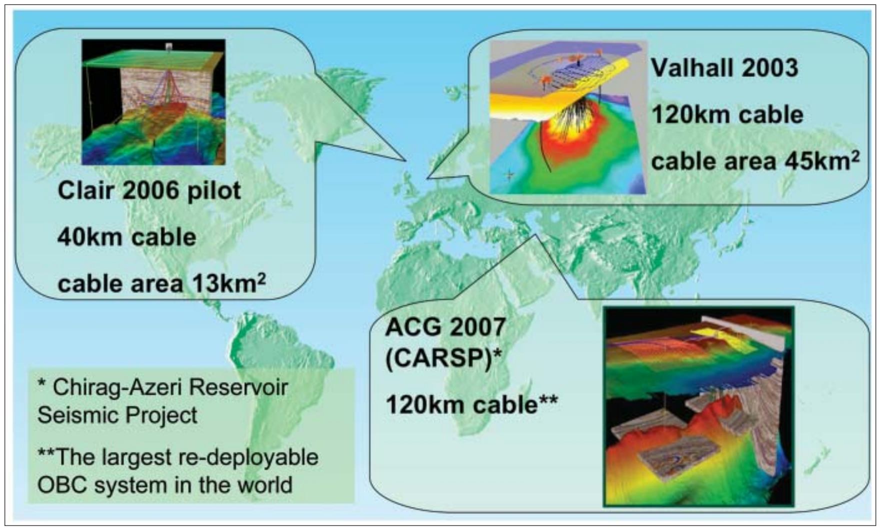

Figure 1. Overview of BP's OBC monitoring systems.

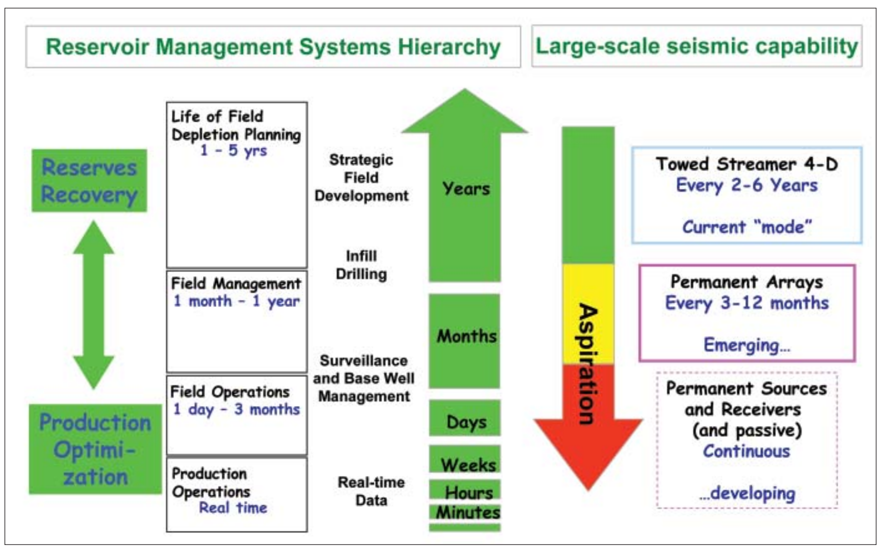

Figure 2. Evolving role of 4D seismic in reservoir management.

The first was over Valhall Field in the Norwegian North Sea in 2003. Eleven surveys have been acquired with the Valhall LoFS system, and these are having an increasing impact on field management and development. (A detailed article on recent progress with the Valhall system is found elsewhere in this special section.)

A small trenched OBC system was installed in 2006 over a pilot area of the North Sea Clair Field Phase 1 development. Soon after this, in early 2007, BP (as operator) initiated a novel OBC system with cables that could be deployed as required to chosen survey areas on the Azeri-Chirag-Gunashli (ACG) complex in the Caspian Sea in Azerbaijan; it is known as the Chirag-Azeri Reservoir Seismic Project (CARSP). Data acquired over Clair and ACG are currently being processed and analyzed.

This paper overviews the current status of BP's three OBC monitoring systems and shows how experience with the well-known Valhall LoFS project has been used to facilitate installation and operations of the similar systems at Clair and ACG. While it is too early to report interpretation results from Clair and ACG, the authors are keen to share the progress made with getting these additional systems installed and running. The expected and emerging benefits of OBC monitoring in general, forged mainly from five years of Valhall experience and supplemented by the process of making business cases for the Clair and ACG projects, are discussed. Finally, the challenges of identifying and justifying future OBC monitoring installations are considered.

The Valhall and Clair systems can be considered truly permanent LoFS as the seabed cables have been purchased and permanently trenched into the seabed, and the associated recording systems have also been purchased and installed. CARSP is somewhat different. Similar equipment was purchased, but the cables have not been permanently trenched and are currently redeployed around the field as required. In the case of Valhall and Clair LoFS, ongoing operations in-

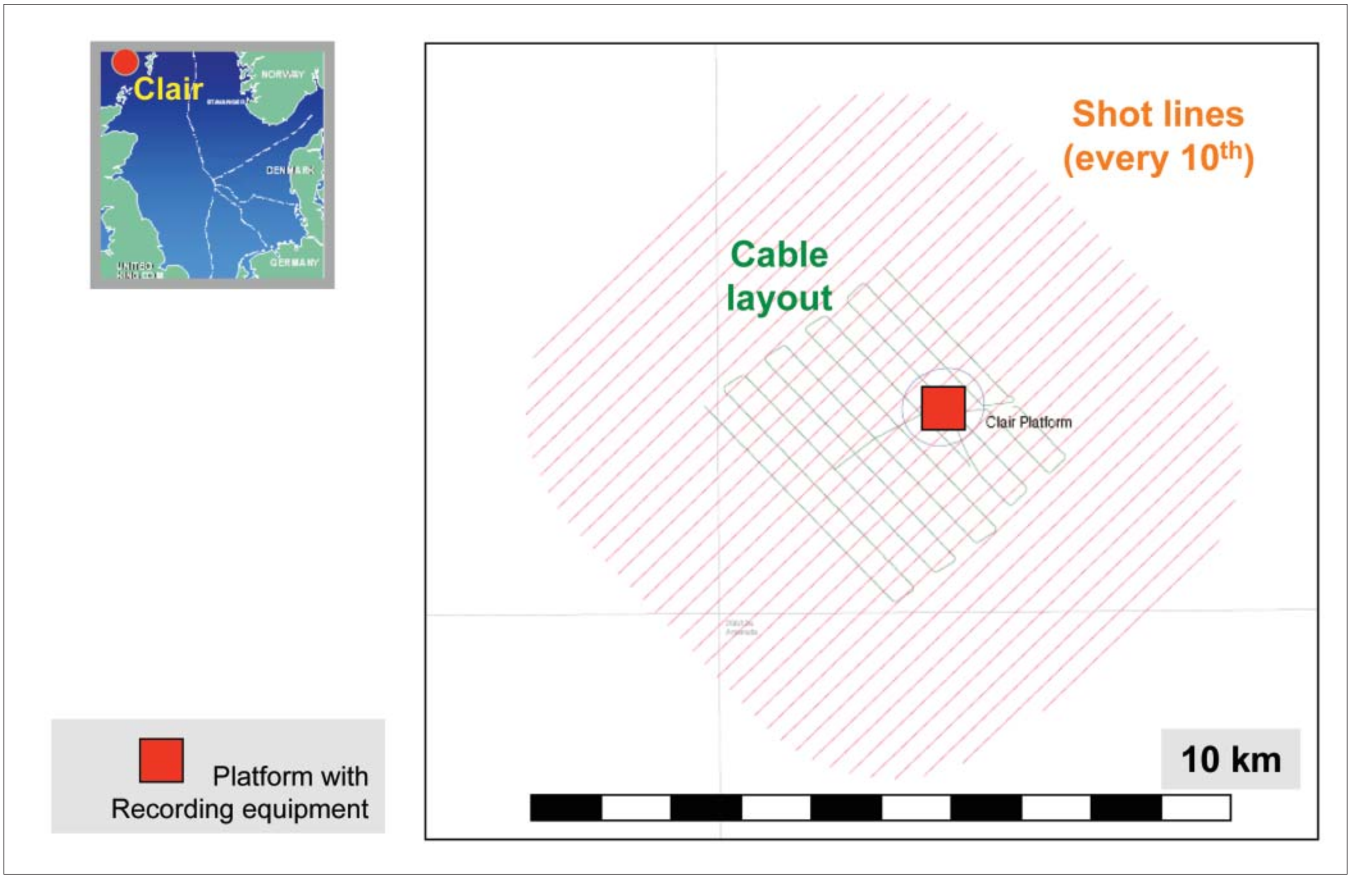

Figure 3. Clair pilot LoFS installation.

volve a vessel whose function is strictly shooting; however, for CARSP, the operations vessel has the dual-purpose of moving the cable and then shooting data. So the CARSP system is permanent in the sense of having purchased equipment tied to facilities as in the true LoFS projects, but in terms of geophysics it is really only semipermanent, as the cables are redeployed. However, we use the generic term "OBC monitoring system" to describe both types of installation to differentiate them from repeated conventional OBC surveys.

Figure 4. Dual-purpose cable operation and shooting vessel Pacific Raider during operations near central Azeri platform. The cable and gun systems are modularized for alternate back-deck deployment.

Expected benefits of OBC monitoring systems

OBC systems, at least in the way they have been implemented in the three BP deployments, promise highly effective seismic monitoring data in terms of both imaging quality and repeatability, and frequency and consistency of surveying. In terms of seismic imaging, high-fold OBC provides wide-azimuth illumination that is the subject of so much recent industry interest and activity. In terms of 4D geometric repeatability, permanent OBC systems have an upper hand due to fixed receiver cables, and semipermanent cables are also expected to deliver good results. Source positions are more easily repeatable (a source boat is generally easier to position than a streamer vessel, but the gap is reducing with new technology). Finally, in terms of delivering a step change in reservoir management, permanent systems (and to a lesser extent semipermanent systems) improve the affordability of regular and frequent surveys (perhaps annual or more frequent) compared to streamer surveys, which are typically acquired only every 2–6 years.

Many oilfield management decisions and interventions are made monthly, and many could benefit from input from seismic surveys on a more frequent basis than is the current norm. (Well engineers on Valhall have been some of the most enthusiastic customers of LoFS data!) There is still some way to go before seismic real-time data using permanent sources and receivers is established (although there have been small-scale tests), but in the meantime, OBC systems provide a significant step in this direction (Figure 2).

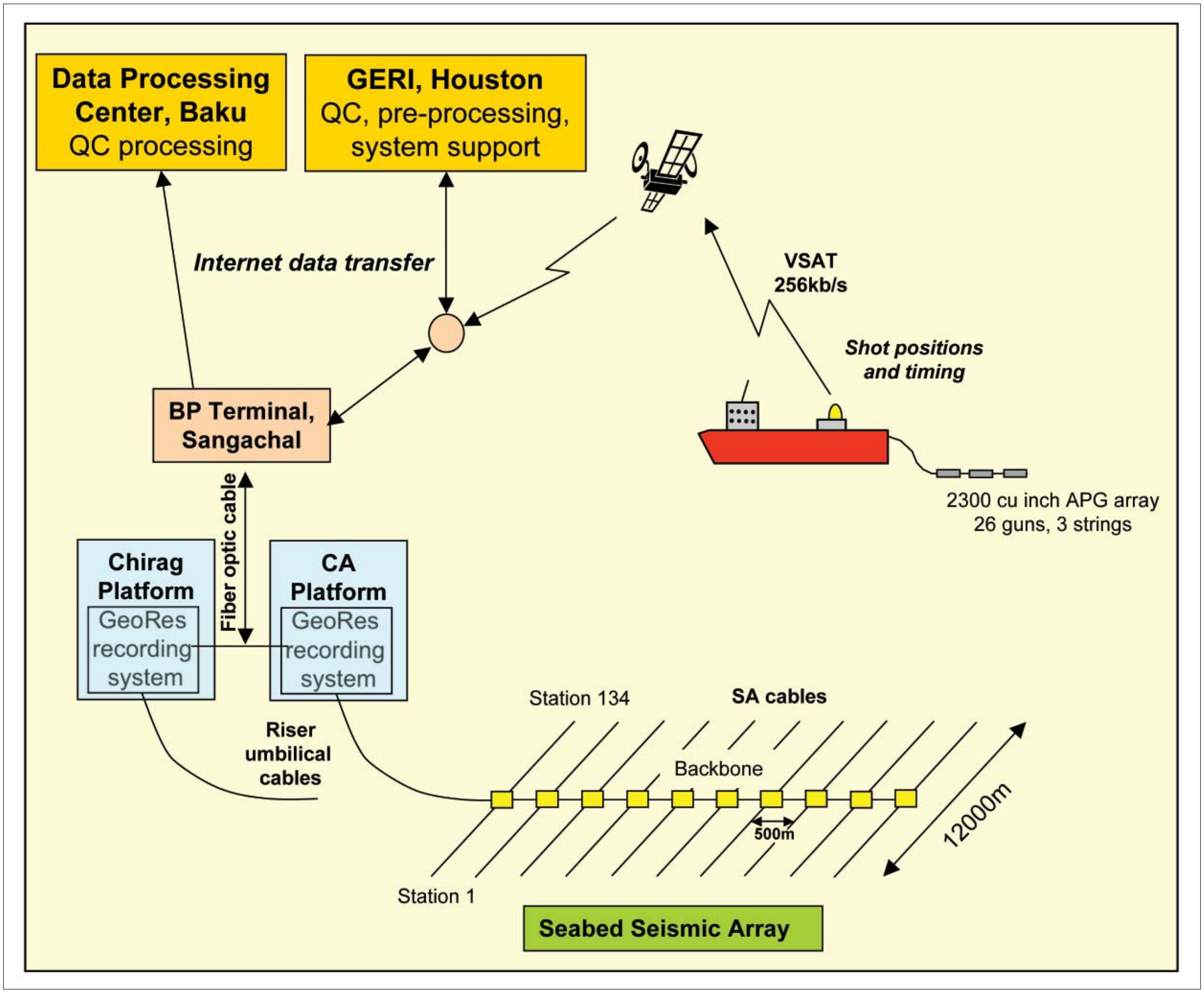

Figure 5. *The CARSP seabed seismic array and recording system.*

The following analyzes the range of potential benefits of permanent or semipermanent OBC monitoring. Again, it should be emphasized that this is an emerging generic view, based mainly on the Valhall experience, but supplemented with the experiences of articulating the business cases for Clair and ACG. It is important for the reader to realize that each of these value sources has varying relevance to each situation, and it is only with further experience and track record that some of these possible benefits will be able to be considered proven, particularly for the new systems at Clair and ACG.

Primary expected benefits are considered to be:

- 3D and 4D imaging uplift due to PZ summed, wide-azimuth high-fold illumination
- Improved geometric repeatability due particularly to fixed or similar positioning of seabed cables and the generally more accurate repeat positioning of seismic sources on a shooting vessel; use of identical or similar sources is also beneficial
- The opportunity for frequent 4D or "seismic-on-demand," although the cost of surveys and the need to move a large cable array reduce the responsiveness of the Azerbaijan solution

The permanent cable systems have the following additional primary benefits:

- Improved cycle time (automation of much of the Valhall LoFS processing and interpretation workflow has dramatically reduced first data and basic interpretation delivery from months to days)
- Ongoing shooting is simplified, lower cost, and with lower HSE risk

Further benefits can include:

- Azimuthal P- and S-wave attributes
- Passive monitoring potential (particularly for permanent arrays)
- PS converted-wave image potential

- Overburden characterization (e.g., for drilling hazard analysis)

Clair LoFS permanent OBC system

In 2006, a small permanent trenched seabed receiver array (40 km of cable covering ~13 km^2) was installed over the up-dip core area of Clair Field's Phase 1 development, and since then, a baseline and two 4D monitors have been acquired (Figure 3).

Ongoing surveys are expected to deliver high-quality 3D and 4D OBC images of this complex, moderate porosity, fractured, Devono-Carboniferous reservoir under early production and water-flood. This initial Clair OBC installation is important as it represents an exciting test of the limits of 4D detectability using such systems in a reservoir where only small acoustic property changes are expected in the matrix.

Experience with conventional OBC acquisition at Clair has already significantly improved 3D imaging and shown that azimuthal seismic attributes are potentially useful in fracture characterization. Also, 3D C-wave data have successfully illuminated parts of the reservoir which have very weak reflectivity on P-wave data.

The permanent installation offers an opportunity to investigate time-lapse changes in these attributes as well as improved detectability of the more conventional 4D attributes, such as P-wave reflection amplitude and traveltimes. Other benefits at Clair of the permanent system include improved 3D resolution as a result of the high fold (25 × 25 m) shot grid compared to the previous sparser OBC acquisition, having the cables buried in the seabed, plus the potential for passive monitoring of microseismicity in the reservoir caused by production depletion and water injection.

Chirag-Azeri redeployable OBC system

In 2007, a novel OBC system using redeployable cables was used for the first time over the Azeri and Chirag fields, part of the giant ACG oilfield complex under early production using water-flood and gas injection. A single multipurpose vessel acts both as cable-handling vessel and source vessel (Figure 4). An array of 120 km of seismic array (SA) cables is deployed in the chosen survey area and connected to permanently installed recording systems on either the Chirag or Central Azeri platforms, using a moveable backbone system of cables and a permanent riser cable to the platforms (Figure 5). Once the array has been connected, the cable crew is replaced with a source crew, and the same vessel is used to shoot a 50-m grid of shots into the receiver array.

Baseline surveys were acquired in 2007, and repeat surveys and a further baseline have been acquired in 2008 (Figure 6). This initial installation, although still considered a pilot, is believed the largest redeployable OBC system in the world.

Earlier conventional towed-streamer 4D over Chirag Field demonstrated the viability of 4D monitoring of water movement in the better imaged parts of the structure. However, narrow-azimuth streamer data give a poor image in some parts of ACG, particularly where shallow gas, mud volcanoes, and steep subsurface dips occur. OBC surveys acquired in

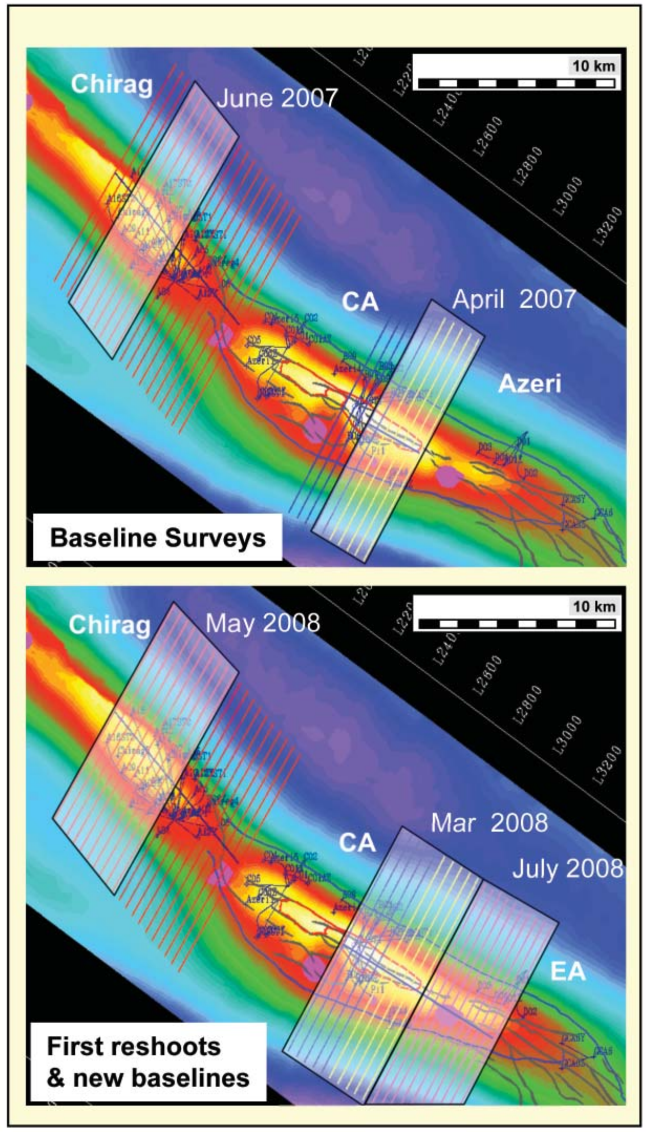

Figure 6. Overview of CARSP Phase 1 surveys during 2007 and 2008.

2002 over the Azeri and Gunashli fields have proven that significant 3D data quality uplift can be achieved through this method.

The redeployable system, which is a key part of the ACG long-term seismic strategy, is designed to be a cost-effective way to acquire 4D OBC data over a large area. Significant design work involving analysis of the earlier OBC and 4D surveys was carried out to ensure both high-quality and cost-effective OBC 4D monitoring. Installing a permanent trenched solution over the entire area at this stage was not considered economic. The compromise of using redeployable cables is still expected to deliver good repeatability, but perhaps not as good as fixed cables. The significantly reduced upfront capital for a moveable system has come at the price of more costly and time-consuming ongoing operations, which include relaying cable in addition to shooting.

As well as the data quality improvement in poor data areas, and despite SIMOPS challenges, the OBC approach has significant advantages for acquiring continuous and effective seismic across a major field complex with a number of facilities (currently five major platform installations). Towed-streamer 4D would now be extremely difficult to acquire over a large part of the field complex area due to the significant number of facility obstructions requiring difficult and expensive undershooting, and/or leaving large coverage gaps.

Preliminary results from the 2007/2008 program have provided sufficient encouragement to acquire further data in 2009 and 2010.

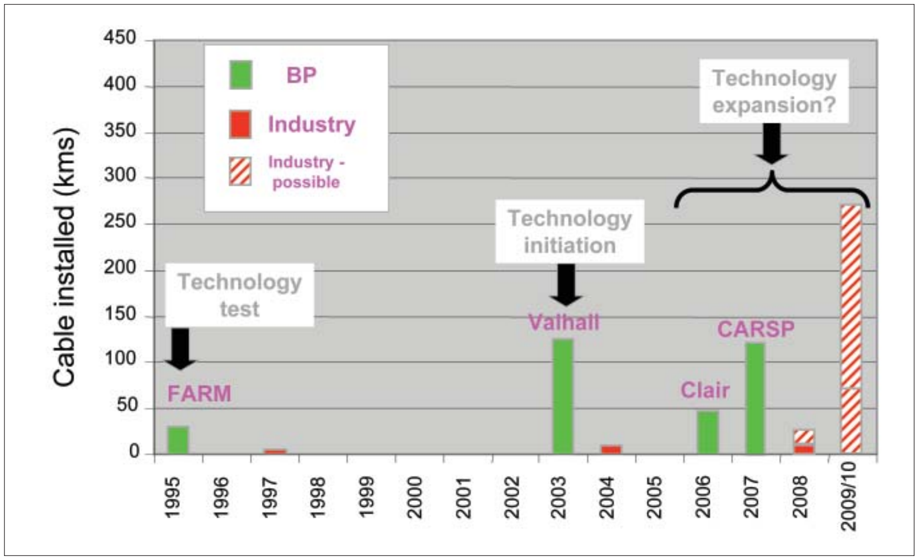

Figure 7. *Industry adoption of permanent and semipermanent OBC monitoring. Timing and scale of potential future industry activity is approximate.*

Discussion

A huge amount has already been achieved in getting BP's and the industry's first three large-scale OBC monitoring systems in place. Technical and commercial challenges have been overcome. Supplier commitment and innovation, and support from partners and government have been critical. It has been a truly "bold move" to begin to affect a step change in seismic reservoir surveillance.

Both the Greater Clair Field and the ACG complex present the challenge of scale whereby a full-field implementation would not be immediately viable. The chosen pilot solutions have recognized the local conditions and have been adapted accordingly.

However, it's important to also realize that there are several common key success factors that have driven and enabled these three initial BP-operated OBC monitoring systems:

- Current projects are generally in more complex and large long-lived oilfields under water flood in contrasting subsurface settings. This gives greater need and opportunity for a sustained seismic surveillance effort to optimally manage the reservoirs over many years, even decades.
- A requirement to overcome significant imaging problems that could not be resolved with the current streamer technology (all three fields had demonstrated an OBC image quality uplift using normal OBC surveys prior to committing to a permanent OBC system)
- A requirement for ongoing and "on-demand" seismic monitoring
- Multiple value sources to justify the high upfront installation cost
- A large number of future wells

These factors have driven successful deployment in Valhall, Clair, and ACG, making the significant capital investment justifiable and potential risks worth taking. For deployment to perhaps smaller and less complex fields, entry cost and risk profiles will likely have to be more favorable.

So, due to a combination of the high upfront capital commitment for these "high-end" 4D monitoring systems and the lack of a fully mature permanent system supply segment, widespread deployment of permanent and semipermanent OBC systems is likely to depend on:

- Understanding system benefits and economics in simpler, smaller fields, perhaps with no inherent need for OBC quality imaging
- Increased industry capability and track record, system cost-effectiveness, and technology enhancements (e.g., fiber-optic sensors and cables)

Despite earlier forecasts of significant interest, industry adoption to date, outside of BP, has been slow and limited to small-scale marine or land installations. However, perhaps in part due to BP's commitment to the first three systems and their emerging success, there is growing evidence that greater momentum with permanent OBC systems is beginning to occur, with many new supplier offers of this capability, and other operators beginning to deploy pilots and even planning full-scale systems (Figure 7).

Conclusions

Major progress has been made in furthering the evaluation of permanent and semipermanent OBC deployments for seismic reservoir monitoring in the marine environment. These systems are not "seismic as we know it," being more like engineering projects, and being approached as such. The deployment learning curve has been steep. Processing and interpretation workflows are being adapted to this new form of frequent monitoring. The positive impact of better reservoir images from high-fold and wide-azimuth OBC is starting to become apparent, but it will be some time before the full economic value can be assessed. It also will be a while before the relative merits of permanent versus semipermanent systems can be properly evaluated.

The Valhall, Clair, and ACG installations have been driven by the need for high-quality OBC monitoring to solve streamer imaging challenges, and enabled by the scale and expected longevity of the fields. These features of the innovator and early adopter fields for LoFS are not unique, but it is likely that for ongoing business cases to be made for smaller and less complex fields, the potential benefits and cost-effectiveness of OBC systems will have to be better understood and optimized. Industry demand, capacity, and experience need to increase to break down the entry costs and risks for this emerging technology. Until this occurs, streamer-based monitoring is likely to remain the mode for a lot of areas, and the potential added technical benefits of OBC 4D will not be realized.

It's now been five years since the first large-scale OBC monitoring system was put in place at Valhall, rapidly followed by the Clair and ACG projects. This is a relatively short time for an industry with conservative technology adoption patterns. Perhaps in the next five years, we will see momentum with OBC monitoring systems fully achieved, making the technology more cost-effective and accessible to a greater number of situations.

Suggested reading. "Continuous seismic surveillance of Valhall Field" by van Gestel et al. (*TLE*, 2008). "The BP 4D story: Experience over the last 10 years and current trends" by Foster (IPTC paper 11757, 2007). "Lessons learnt from over 20 years of 4D deployment" by Foster (SPE paper 113542, 2008). "Improved P-wave imaging with 3D OBS data from Clair Field" by Kommedal et al. (*First Break*, 2005). "Clair 3D/4-C demonstrating the value in reprocessing 3D multicomponent surveys" by Ashby et al. (EAGE 2007 *Extended Abstracts*). "3D/4-C and 4D ocean bottom seismic surveys in the Caspian Sea" by Bouska (OTC paper 18671, 2007). "Developing the long-term seismic strategy for Azeri-Chirag-Gunashli, South Caspian Sea, Azerbaijan" by Howie et al. (*TLE*, 2005).

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