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The 4C Node Solution for Improved Reservoir Monitoring

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Summary

It can be demonstrated that the background response from well planted nodes can be repeated in a 4C-4D scenario when the coupling conditions are the same. The vector fidelity in the node system will secure this behaviour. In addition will the accurate positioning and re-positioning of the nodes under realistic water depth ranges secure positioning accuracy close to permanent buried cable systems.

In the evaluation of realistic 4C-4D scenarios of smaller and larger fields it can be shown that nodes are competitive with buried cable systems. In addition is the advantages linked to acquisition geometry and operation, equipment life time risk and low initial investment.

Introduction

The autonomous node technology has been developed to a fully commercial system within the last ten years. It has demonstrated its capability, in areas like the Cantarell Field in Mexico, to improve imaging of complex reservoir structures with both pressure (PP) and converted shear (PS) data compared to previous OBC surveys. The main reasons for these improvements are the stable and consistent measurements achieved by very well planted nodes as well as the full azimuth acquisition with densely sampled shots.

The stability of coupling of planted nodes from location to location in a very soft sea bottom environment was clearly demonstrated in the pre- processing of the data using a 3DFK filter which successfully attenuated severe field noise in the common receiver domain. The success of this method could only be achieved by very accurate vector response where there is no instrumentation "footprint" in the data (see Figures 1 and 2)

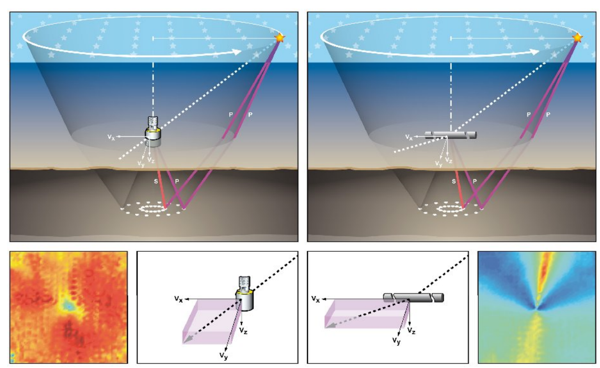

Figure 1: The vector fidelity anylysis of nodes and cable experiments demonstrate different vector responses where the first break energy for the cable is be more aligned up along the cable direction

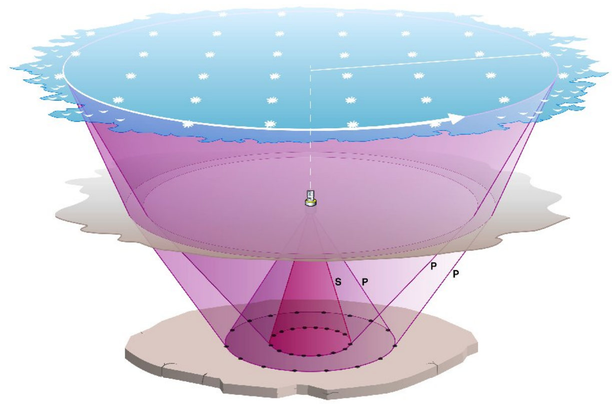

Figure 2: The importance of vector fidelity during dense full azimuth shooting is essential in order to avoid intrument footprints in the data.

Experiments and Methodology

An experiment performed on the Volve field in the North Sea with pairs of nodes planted side by side clearly confirmed the high degree of stability in the coupling and the repeatability of the measurements from all components. By taking the differences between common receiver gathers of neighbouring nodes as seen in Figure 3, 4 and 5 was demonstrated that nearly all the reflected energy disappeared leaving only the direct arrival and low-energy Sholte-waves. In this case the same shots were used, but y comparing neighbouring nodes (1m apart) using different shots (three weeks between the shooting) the same tendency is observed, although the general noise level has increased. In the quantitative analysis using all 12 paired nodes and two different 3D shooting carpets, it can be shown that the pairs of nodes observing the same shots seem to give higher degree of repeatability than the same pairs of nodes seeing different shots.

Figure 3: The two nodes coupled to together in other to verify similar coupling responses on records.

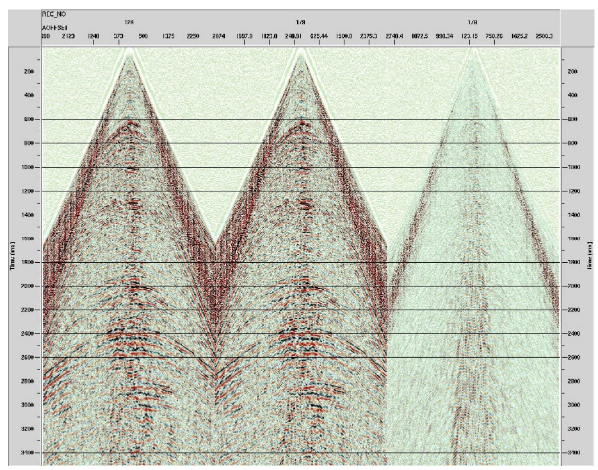

Figure 4: CRG PZ comparisons of neighbouring nodes 1m apart and their similar responses as seen on the difference plot on the right with the same shots

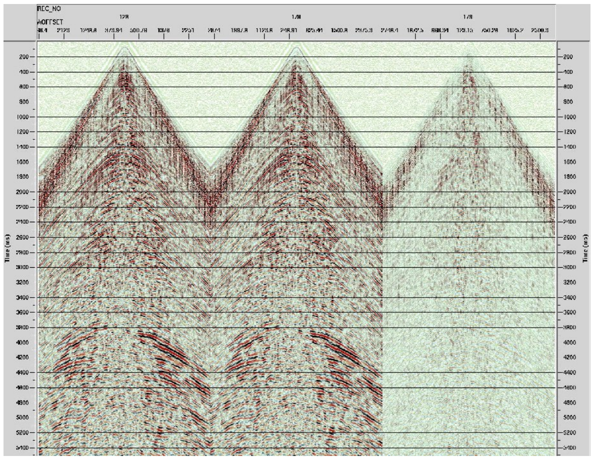

Figure 5: CRG Radial Vr radial component comparisons of horizontal components where the difference plot is on the right using the same shots.

In addition to the coupling characteristics the positioning and re-positioning of the nodes is essential in a 4D scenario. At the Volve Field in the North Sea at 100m water depth the positioning accuracy of planted nodes was 1.5 m as compared to the defined pre-plot position for 95% of the 143 nodes deployed and planted.

Since large offsets are essential in a node 4C- 4D scenario the source characteristics should be as omni-directional as possible. This is important in order to achieve high quality PP and PS data in the base survey as well as in the monitor repeats.

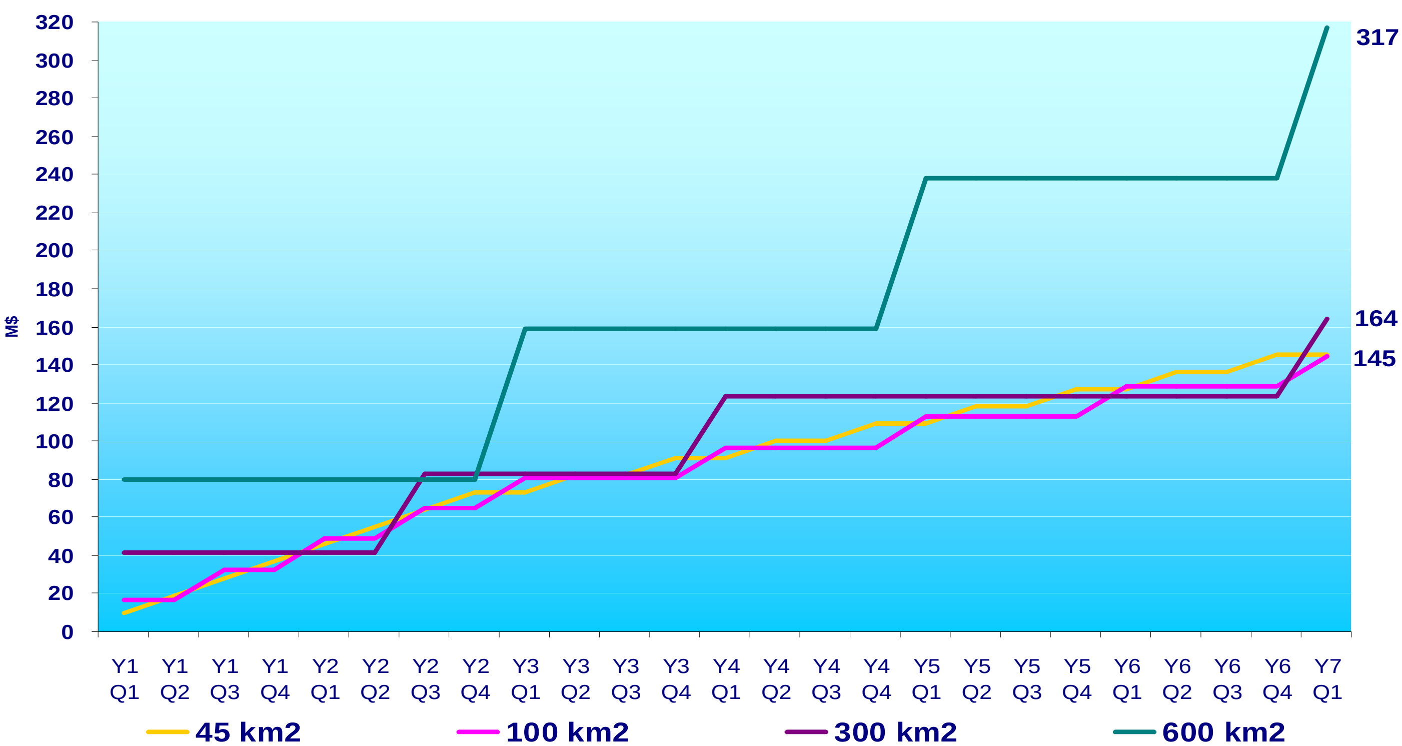

Figure 6: A comparison of cost in a shallow water case with 300m node spacing and cumulated costs in million USD as a function of time.Note the similar behaviour of 45km2 and 100km2 concerning costs.

A cost sensitivity study of analysing different 4C-4D node scenarios with respect to field size, water depths and node spacing is clearly showing that the alternatives with larger field sizes (300-600km2 receiver coverage) are more cost effective as summarized in Figure 6. During a 6 years monitoring period the cumulated cost pr km2 receiver area will be within the range of 0.5-1.0 mill. USD. If the regular node spacing is reduced from 400m to 300m the typical cumulated cost will increase by 20-40%, depending on water depth and field size.

A direct comparison of the 45km2 North Sea Valhall Field trenched/buried cable project and a similar node 4C-4D scenario over the same area shows that the buried cable is getting less expensive than the node scenario after 7-8 years and 10-12 monitor repeat surveys. It should be noted that the field size (45km2) is relatively small and that the monitor repeats are as frequent as every quarter. In scenarios with larger field sizes and less frequency of the monitor repeats (i.e. half a year to two years) the node scenarios are getting more and more competitive compared to trenched/buried cable systems.

Conclusions

The accurate repeated positioning of nodes and the fulfillment of the vector fidelity allow the node concepts to be a very reliable alternative in 4D scenarios.

In comparison with buried trenched cable systems the node concept is a very interesting alternative when the fields are larger and the 4D requirements are high.

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