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Very High Resolution 3D seismic: a new imaging tool for sub-bottom profiling

short english version (*)

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Abstract:

This note presents the first results of the development of a 3D Very High Resolution seismic method. Particular attention was paid to the design of an operational system to be in agreement with the expected goals in term of acquisition and processing. A set of three examples, collected in various geological environments, is presented.

Key words : Seismic, VHR, 3D

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1. Introduction

The water bottom and its near subsurface are by nature 3-dimensional structures and should be treated as such, which exclude 2D approximation.

From the imagery point of view, the main key constraints for a survey design are the following: maximum depth and dip of layers, horizontal and vertical resolution. These constraints may, in turn, be related to the acquisition geometry addressing the following parameters: signal frequency bandwidth, trace length, trace interval, streamer length, streamer spacing, line spacing and shot interval.

The proposed 3D acquisition system (figure 1) was designed for optimal coverage of sites of limited extent (2 km * 1 km) in water depths up to 100 metres and a target vertical resolution of 1 metre. Investigation areas might include large geotechnical sites (dams, artificial island sites, pipelines routes on the continental shelf …) or sedimentary bodies of key geological importance.

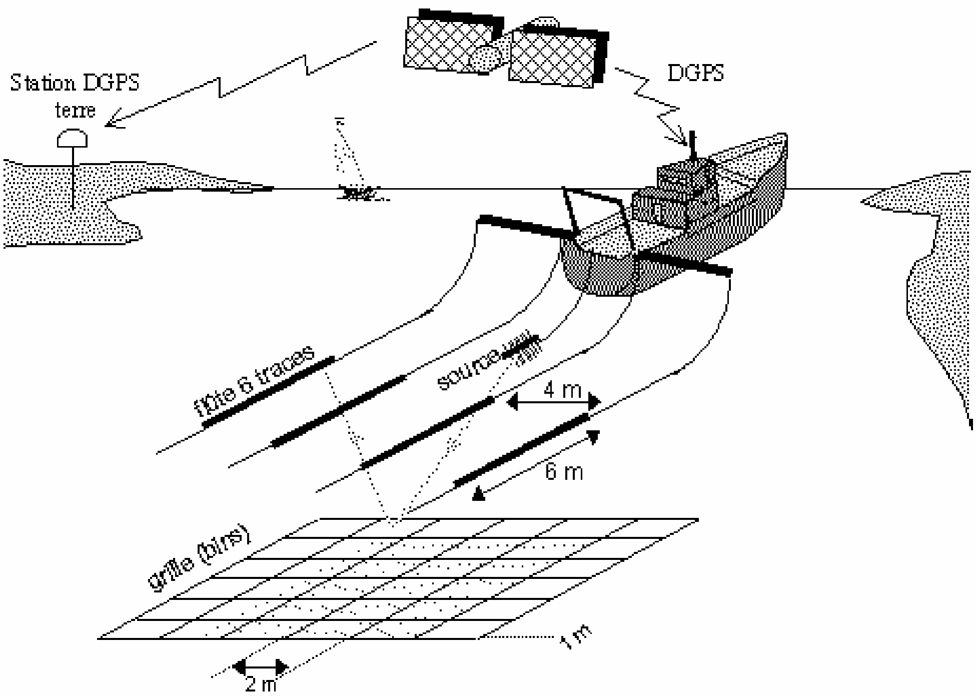

Figure 1 : Artist view of the proposed 3D seismic acquisition device, the length of the seismic traces (2 metres) associated with a streamer spacing of 4 metres lead to a theoretical bin size of 1 * 2 metres.

2. Methodology

The term Very High Resolution (VHR) seismic stands for a resolution of submetric scale in the medium; yet, seismic sources are to provide with adequate frequency content: sparker technology appears to be the most suitable answer to the needs of the project, yet leading to a frequency bandwidth centred on 700 Hz.

The success of any water-borne VHR 3D seismic method depends on highly accurate positioning of both seismic source and receivers. The approach is two-sided:

- Absolute positioning, i.e. with reference to an ellipsoid.

- Relative positioning, i.e. source–receiver positions with respect to each other. The proposed solution to handle relative positioning is based on numerical inversion of direct/ reflected traveltime ; although this problem is clearly under determined, simple assumptions may easily be added to constrain the solution.

In order to design 3D processing sequences, direct modelling was used to compute synthetic seismograms: Pre-stack migration routine, involving an adapted Kirchohff depth migration, turns to be the most efficient algorithm to handle the irregular acquisition grid.

3. Application

Three geological targets were successfully surveyed within the project:

- A site in the Mediterranean Sea (1998) – located in the gulf of Aigues Mortes – was selected for the existence of highly contrasted lithology linked to sea level changes since 18 000 BP in a river mouth area (figure 2).

- A site in the Dover Strait (1999) – located off Cape Gris Nez – was chosen in a tectonised environment where folds and faults affect Jurassic limestones (figure 3).

- A site off the south coast of Cornwall (2000) - located in St Austell Bay - was chosen on the basis of access to existing geotechnical and geophysical data. The location provides an unconsolidated sequence of sands and clays in a fluvial environment, including peat beds and cobbles overlying a consolidated shale (Devonian) substrate (figure 4).

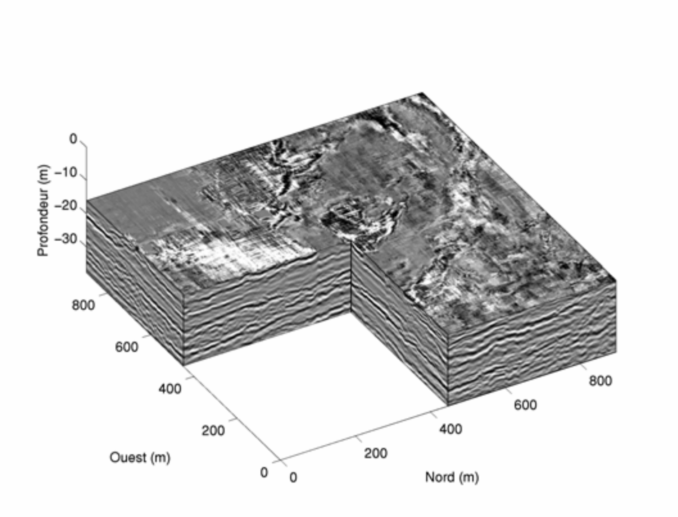

Figure 2 : 3D block - Aigues-Mortes : Trial area characterised by very different lithological environments made of fine-grained sediments (homogeneous grey seismic facies) alternating with coarse-grained sediments (chaotic seismic facies)

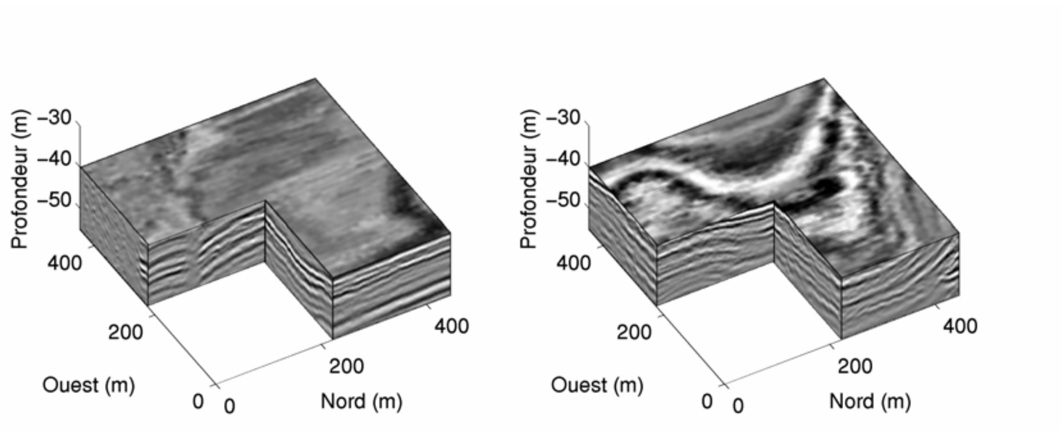

Figure 3 : 3D block - Boulonnais. Trial area displaying lithological features in carbonate sets. the left block shows a fault and the presence of gas, the right one shows the transition from anticline to syncline shape.

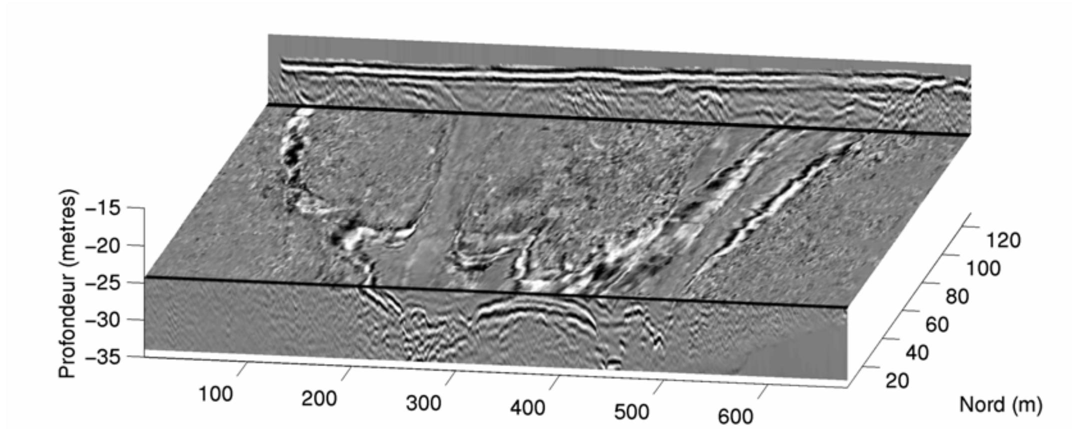

Figure 4 : 3D block - St Austell . Trial area imaging a network of paleo-valleys. Note, on the left, the confluence of two valleys. The filling of the paleao-valleys is characterised, from bottom to top, by chaotic seismic facies evolving to low energy seismic facies suggesting the evolution from coarse-grained to fine-grained sediments.

4. Conclusion

The presented approach has allowed to successfully downscale 3D seismic surveying to VHR studies, nevertheless the method is limited to targets of limited extent. A new project was started in January 2001 to develop affordable 3D seismic adapted to HR studies.

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