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Illuminating sub-seafloor structures in 3D with Swath-Seismic mapping

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Introduction

The understanding of the formation and evolution of continental margins would greatly benefit from the possibility to map large-scale three-dimensional subsurface structures. Swath-bathymetry mapping provides detailed maps of seafloor bathymetry efficiently but presently no similar method exists to map subsurface structures. However, most continental margins are covered by a sediment blanket that masks structures formed during rifting or fluid-related features. Targets include the top of the basement and rotated fault blocks formed during continental rifting, distribution of lava flows in volcanic margins, and BSRs, diapirs and other fluid-related structures across continental margins. These structures are usually only mapped by widely spaced 2D seismic profiles and thus their detailed structure and their inventory are poorly known. While 3D seismic surveys are useful to map burried structures in great detail, cost and logistical shortcomings of 3D seismic methods implies that they are rarely used by academia and when used only to map small areas. To bridge the gap between widely spaced 2D seismic lines and 3D structure we are developing the swath-seismic mapping method. We present first results on the development of this new seismic method designed to map subsurface structures across large areas of the continental margins in relatively short acquisition time.

Method

The philosophy of the method is based on the acquisition with a seismic "antenna" in form of an areal distribution of hydrophone nodes, which can be used to separate the incoming seismic wavefield into plane wave components discriminated by the direction of arrival. This is an extension of earlier investigations by Slotweg (1986), leading from a side-looking (only perpendicular to the ship-track) beam-forming concept towards a full 3D migration algorithm based on azimuthal processing. This is accomplished by the rotation, binning and stacking of common azimuth gathers with subsequent slant-stack transformation into the azimuth-inclination-angle section. We obtain the wavefield sampled in spherical coordinates which enables us to identify regions of interest with prominent backscattering amplitudes. These azimuth-incident-angle sections are than used as input for a beam-migration algorithm to provide improved sub-surface images through stacking of multiple shots by increasing the fold and coverage (signal/noise ratio). The information on geological features provided by the azimuth-inclination-stack section can be used to focus the migration operator and thus make the computation more efficient.

Implementation

Within a pilot-phase of the Euromargins-Swathseis project we developed the core of the seismic processing and imaging software. The development of the algorithm and first software tests have been performed on simple synthetic data-sets. The antenna geometry of 81 hydrophones aligned in 9 parallel streamers spanning an area of 50m x 50m with 6.25m spacing was choosen to compromise between the required spatial sampling and the minimum spread for the slant-stack transformation with respect to the signal frequency on one hand and the scale of the sub-surface targets to be resolved at this signal frequency and the maximum dimensions to be handled on the research vessels to be used on the other hand. The simple synthetic model is composed of two point diffractors representing buried sea-mounds and diapirs and a line diffractor simulating a basement (e.g. magmatic/volcanic ridge). A plane reflector above these features represents the sediment cover. The (kinematic) synthetic seismograms are obtained using a 60Hz wavelet. The azimuth-binning and -stacking was performed with optimal binsize of 5m. The azimuth-inclination-stack sections are computed at 0-45° incident angles(inclination) with azimuth ranging from 0-360°. Therefore we obtain a swath-width of twice the waterdepth.

To reduce the requirement on memory and computation time azimuth-incident-angle sections are transformed into cylindrical coordinates and the beam-migration is performed in this domain.

Conclusion

The first results with a constant velocity wavefield and migration are encouraging and the implementation of a 3D traveltime solver for arbitrary velocity functions is currently in process. Further tests with 3D seismic data provided by industry is underway. The method under development has the potential to fill the gap between 3D-seismic methods providing detailed information on small areas and large scale 2D-seismic surveys with little information on structural changes between survey lines. Thus, we present a method to obtain three dimensional images of large scale subsurface structures in relative short time.

References

Slotweg, A.P. 1986: Basement imaging with side-looking seismics. Mar. Geophys. Res. 8, 149-174