HIGH RESOLUTION SHEAR WAVE MODELLING OF OBS DATA IN A GAS HYDRATE ENVIRONMENT IN THE DANUBE DEEP-SEA FAN, BLACK SEA

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Abstract
The Danube deep-sea fan, with his ancient and recent meandering canyon systems, hosts multiple bottom-simulating reflections (BSRs) observed in high-resolution reflection data, indicating the occurrence of gas hydrates and free gas. To image the distribution of submarine gas hydrates and the occurrence of free gas in a channel-levee system, fifteen ocean bottom seismometers (OBS) were deployed. The OBS data in particular reveal information about seismic P- and S-wave velocities of the subsurface. They record wavefields of a wide range of incidence angles, thus, allowing for an estimation of density and porosity of the sediment layers.

Keywords: Seismics, Danube Fan, Black Sea

With his ancient and recent meandering canyon systems, the Danube deep-sea fan mainly controls the slope at the Bulgarian and Romanian margin of the western Black Sea. This channel-levee system hosts multiple bottom-simulating reflections (BSRs) observed in high-resolution reflection data [*Popescu et al., 2006*], indicating the occurrence of gas hydrates and free gas. In the scope of the multidisciplinary research projects "SUGAR" and "MIDAS" the German research vessel Maria S. Merian (cruise MSM34-2) conducted high-resolution 2D and 3D multichannel seismic reflection data and ocean bottom seismometer (OBS) data, along with acoustic and heat flow measurements, as well as gravity coring for geochemical analysis. The goal of the active seismic experiment is to image the distribution of submarine gas hydrates and the occurrence of free gas in the Danube deep-sea fan. The OBS data in particular reveal information about seismic P- and S-wave velocities of the subsurface. They record wavefields of a wide range of incidence angles, thus, allowing for an estimation of density and porosity of the sediment layers.

Fifteen OBS stations equipped with hydrophones and three-component seismometers were deployed in a grid distribution and recorded source signals from a 45/45 cinch Generator Injector (GI) airgun. Eight 2D lines (11 km to 14 km length) that extend beyond the area of the 3D P-Cable acquisition were shot. For the 2D lines the shot interval of 5 s resulted in a shot distance of ~10 m. Frequencies up to 300 Hz with the main energy at about 100 Hz were recorded. All fifteen instruments show good data quality. The hydrophone data were used to determine a seismic P-wave velocity image of the subsurface. As a result of overamplification the direct wave is clipped in the near-offset and thus not suitable for an amplitude analysis. However, ten seismometers had good coupling to the seafloor and the recorded converted shear waves could be used for S-wave traveltime analysis and provide amplitude information. The frequencies of the S-waves are much lower than the P-wave reflection signals. This is characteristic for shear waves in unconsolidated sediments where the S-wave attenuation is high [*Zillmer et al., 2005*]. The first S-wave appears at ~0.7 s after the direct wave. Some of the S-phases can be traced up to 3.5 km in offset to the station.

Both, P- and S-wave traveltime modelling cover a depth down to 1.5 km below the seafloor; thus, providing seismic velocity information far below the BSR. The seismic P-wave velocities increase with depth from ~1600 m/s beneath the seafloor up to ~2400 m/s at 1.5 km depth. In OBS data, the BSR shows up with inverse polarity compared to the direct wave. Within the seismic multi-channel data, locally, the reflector of the BSR cuts the reflecting phases of the sediment layers. This could be partly observed in the 2D OBS data as a phase separation between the BSR reflector and the reflectors of the sediment layers. In order to fit the refracted and reflected phases and match the inverse polarity of the BSR reflector a negative velocity jump below the BSR was introduced. This is interpreted as occurrence of free gas below gas hydrate at the lower limit of the hydrate stability zone. It is not possible to detect the top of the gas hydrate zone and the bottom of the free gas zone using seismic P-waves only.

The observed shear wave phases did not resolve the above described phase separations. Shear waves in general are not sensitive to changes in the pore fill; however, gas hydrate can increase the sediment shear stiffness, causing an increase in seismic S-wave velocity [*Yun et al., 2005*]. The seismic S-wave velocities increase from ~240 m/s beneath the seafloor up to ~1100 m/s at a depth of 1.5 km below the seafloor. From these observations the P-to-S ratio can be derived and densities and porosities can be estimated. The P-to-S ratio might also help to estimate the thickness of the zones with gas hydrates and free gas, while there will be a limited capability to constrain their concentrations.

This work was completed in the course of the SUGAR-III project funded by the German BMBF (grant 03G0856A).

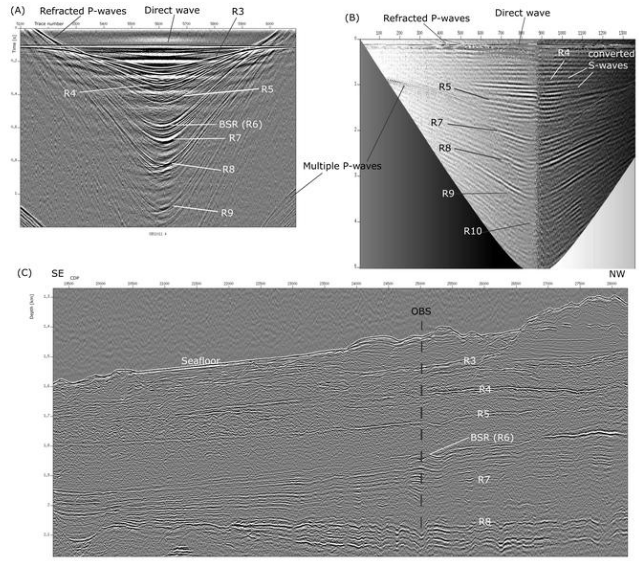

Fig. 1. Data example of OBS1011 along P1103: (A) Hydrophone, showing a wavefield mainly consisting of P-wave energy. (B) Radial component from the Seismometer, showing S-wave energy, while P-wave energy is suppressed. (C) Multi channel seismic data of P1103. Interpreted reflectors are marked in all three seismic sections.

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