Shallow-source/Deep-receiver Marine Seismic Profiling

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Goals

To develop and test an acoustic imaging system to investigate and monitor the hydrates stability zone in the Gulf of Mexico.

BACKGROUND

The shallow-source/deep-receiver (SSDR) seismic method is a marine reflection method that can be applied to image shallow subsurface at deep water depth. It combines a fixed source/receiver geometry (Figure 1) with a customized digital processing sequence. Its development has progressed with the increasing need to image the hydrate stability zone, along the continental slope in the northern Gulf of Mexico, a distance of about 400-800 meters beneath the seafloor. This zone of critical importance in hydrates stability has traditionally been neglected by the oil industry as too shallow to be of economic interest and too deep to be of interest from an environmental or hazards perspective.

In the SSDR method, the seismic source is deployed near the surface of the water and a hydrophone receiver is deployed directly below at a depth that is in the source's far field. It is important that the water be deep enough that the reflection from the water bottom does not interfere with the recording of the direct wave. Interference is avoided only if the two-way travel time from the hydrophone to the water bottom exceeds the duration of the water-bottom reflection (Figure 1); the direct wave can then be used to shape all reflected wavelets, enhancing the resolution of the seismic image.

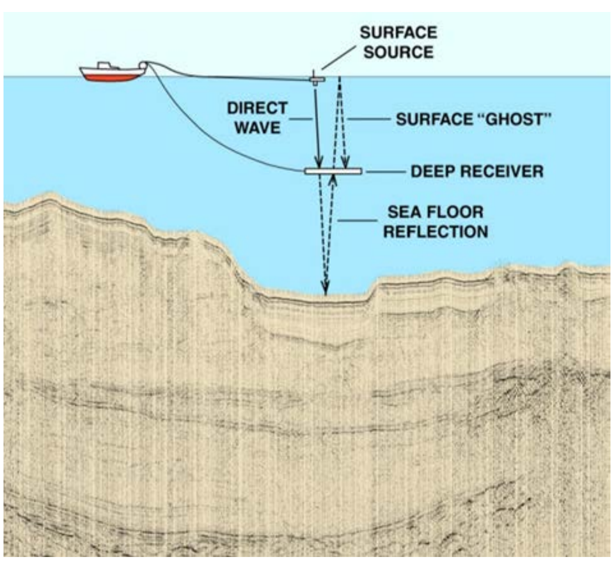

Figure 1. Illustration of SSDR recording geometry

DATA PROCESSING

Single-channel marine seismic data are corrupted by low-frequency noise that cannot be removed by filtering without distorting the seismic images. Researchers at the University of Utrecht, devised a method of modeling the noise and removing it by subtracting the model from the data. The SSDR method employs this "detrending" as an alternative to low-cut filtering. By minimizing filtering and maximizing sampling rate, i.e. oversampling, the SSDR method achieves an increase in number of samples that serves to increase the statistical robustness of the data volume that translates to smoother representations and improved processing results. Oversampling increases the size of data volume; however, increases in memory and speed of processing make this of little practical concern.

Beginning in 1999, the SSDR method was applied to field surveys by the technical staff of the Mississippi Mineral Resources Institute of the University of Mississippi. Two processing techniques, deterministic deconvolution and phase conjugation, were applied to test which was better to enhance seismic resolution. The noise level was found to be increased by deconvolution more than by phase conjugation and it was decided that the latter technique was more effective and should be included in the processing sequence (see Figure 3).

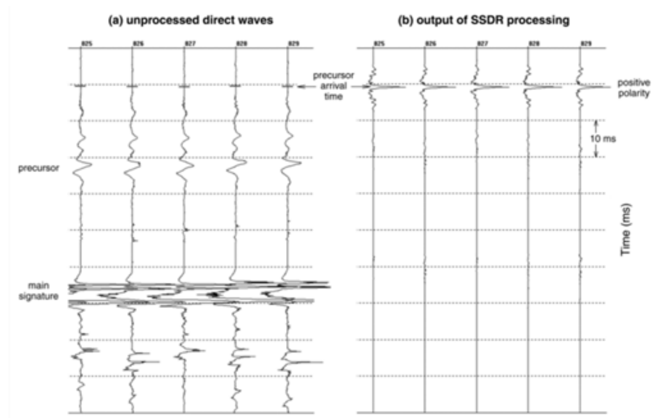

Figure 2. Water gun signature processing. The raw water gun far field signature (a) is a broad and inconsistent seismic pulse; phase conjugation processing (b) collapses the pulse into a narrow signal increasing the vertical resolution, Macelloni, et al., 2011.

SSDR SURVEY OF MC118

In 2006, a grid of SSDR profiles was recorded over the three-by-three kilometer research reserve in Mississippi Canyon Block 118 (MC118). Using an 80 cu.in. watergun seismic source and recording 100,000 samples per second, sub-bottom penetration of about 400m was achieved, sufficient to span the gap between shallow chirp-sonar surveys and oil industrystandard multichannel 3-D seismic surveys. Geophysicists of the Gulf of Mexico Hydrates Research Consortium incorporated the grid into a structural model of the carbonate/hydrate mound in MC118. The SSDR grid imaged the interior of the hydrate stability zone and made it possible to tie shallow chirp-sonar 2-D profiles to a 3-D volume of deep seismic data (Figure 3). Examples of details achievable using the SSDR system are illustrated in Figure 4.

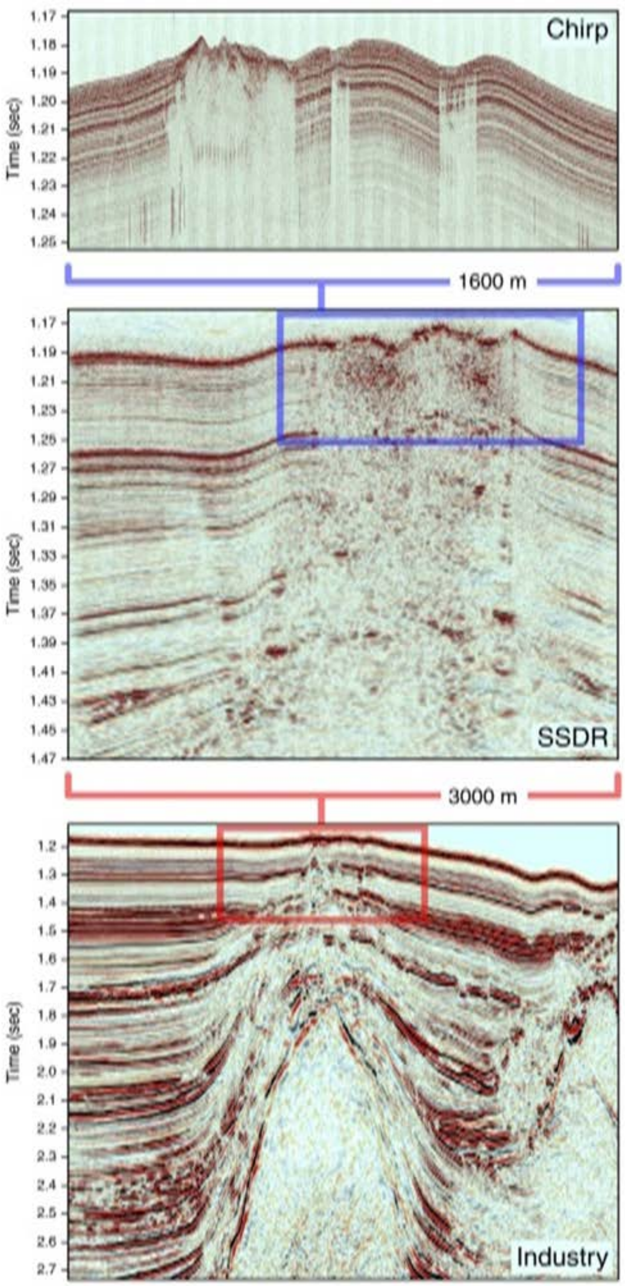

Figure 3. A multiple seismic data resolution approach provides maximum resolution to depth. High-resolution chirp profile (top) details the top .04 sec (~30mbsf), the SSDR (middle) shows the best resolution of the next .40 (~300) and the low resolution industry

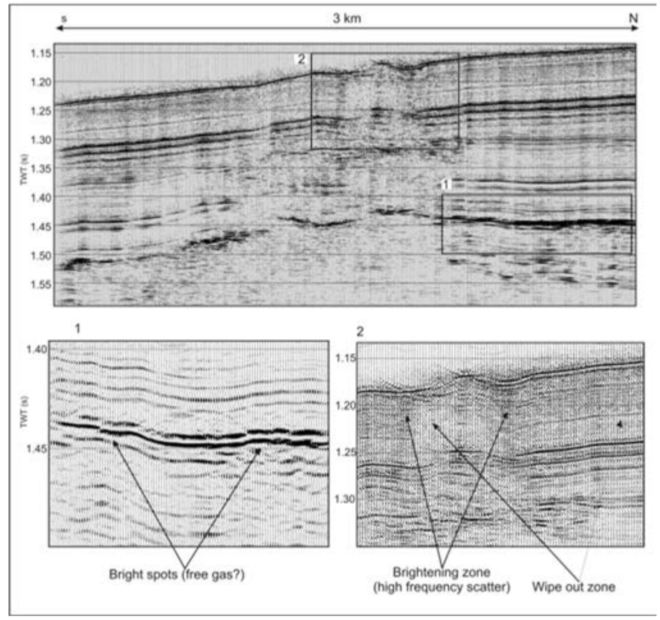

Figure 4. This line runs north (right) to south (left) over a venting location. Free gas and/or pore fluids driven away from underlying salt are reaching the seafloor. Areas within the boxes show a possible reverse polarity bright spot (box 1), interpreted as free gas, and characteristic amplitude wipeout (box 2). Also, a new form of brightening areas are seen throughout the system (box 2).

In a towed system, it would be preferable to eliminate the tow-cable completely by mounting the receiver on an autonomous underwater vehicle (AUV). The National Institute for Undersea Science and Research's (NIUST's) Eagle Ray AUV at the University of Mississippi is scheduled for modification that will equip it for this purpose. Clearly, AUV operations include communication and control by acoustic signals in the water and will introduce acoustic noise that could be more difficult to eliminate. This challenge is being addressed by the CMRET/UVTC teams.

Collaborators

National Institute for Undersea Science and Technology (NIUST)

C&C Technologies

Bureau of Ocean Energy Management (BOEM)

Lookout Geophysical

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