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Monitoring Seafloor Instability Caused by the Presence of Gas Hydrate Using Ocean Acoustical and Geophysical Techniques in the Northern Gulf of Mexico

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The northern Gulf of Mexico is characterized by an extremely heterogeneous near-surface geology that makes geophysical identification of subsurface gas hydrate challenging and ambiguous. Bottom Simulating Reflections (BSRs) that generally are associated with the presence of hydrates are rarely reported.

This paper describes a set of novel seismic experiments designed to characterize the subsurface hydrate distribution at Mississippi Canyon Block 798 in the northern Gulf of Mexico. The sea floor at the survey site lies within the hydrate stability zone and heat-flow data indicate that the zone may be 400 m thick. Sediments near the sea floor are characterized by relatively weak seismic reflections. It is possible that the weak reflectivity partially is due to cementation by gas hydrates. In one region, shallow sediments are underlain by chaotic, sharply stronger reflectivity typical of free gas.

The conventional seismic techniques often fail to image the complex geological features, especially around and under salt domes and sills or in gas hydrate presence that have high propagation velocities for seismic waves. The conventional 3-D marine seismic survey generally acquires several 2-D lines over the target area. The source vessel pulls the streamer carrying receivers positioned on the same line where the source is activated. Thus, source-receiver azimuths follow the direction of those 2-D lines. This means that all the energy spread away from the 2-D profile is missed. Missing energy is responsible for the lack of illumination in most targets under complex geology. Therefore, new techniques in data acquisition and processing are sought to improve the image of complex areas. One of the new seismic data acquisition techniques is the vertical cable. In comparison with the conventional method, VLA method provides advantages such as flexibility during operation to cover the surveyed area, recording the signal in a quieter environment, and an opportunity for direct separation of up-coming and down-going wavefields.

There is interest in using vertical arrays of hydrophones to monitor near-sea-floor gas hydrates and image features within the hydrate stability zone in the northern Gulf of Mexico. A vertical line array (VLA) of hydrophones, specially designed for high resolution in the shallow sediments, was deployed recently by the Center for Marine Resources and Environmental Technology (CMRET, University of Mississippi) with the general objectives of (1) acquiring very high resolution seismic reflection profiles in 850m of water depth, (2) studying the acoustic character and features of the sea-floor for evidence of sea-floor hazards, and (3) looking for evidence of subsurface gas hydrates and their properties.

Signals from a surface-towed seismic source were also recorded by CMRET and multichannel seismics by the USGS at the same site. A horizontal hydrophone array was towed some distance below the source to record simultaneously a near-zero-offset seismic reflection profile.

Conventional and non-conventional preprocessing was done on both the high-resolution seismic reflection and the VLA data. Reflection coefficients were also computed. Both results indicated complex geological settings and velocities that could be caused by seafloor methane hydrate accumulations associated with hydrocarbon seeps. Salt domes and fluid flow features were also identified in the area.

However, with the unconventional acquisition geometry, the VLA data can not be treated directly by the conventional procedures of seismic data processing. Therefore, new algorithms had to be created.

In order to process the data and extract the most information from the VLA profiles, an integrated inversion was developed by combining the ocean acoustic method of matched field processing with the conventional seismic technique of phase shift migration. The inversion provided velocity profiles and information about other physical properties of the near-surface sediments, including a density model.

The comparison between the inversion of the seismic reflection data collected in 1998 by the USGS and the VLA and reflection seismic data collected in 2003 by the CMRET provided the means to monitor/follow changes in the near-surface sediments that can be associated with the presence of gas hydrate.

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Specialized data processing was made by Lookout Geophysical Company Software of Palisade, Colorado.

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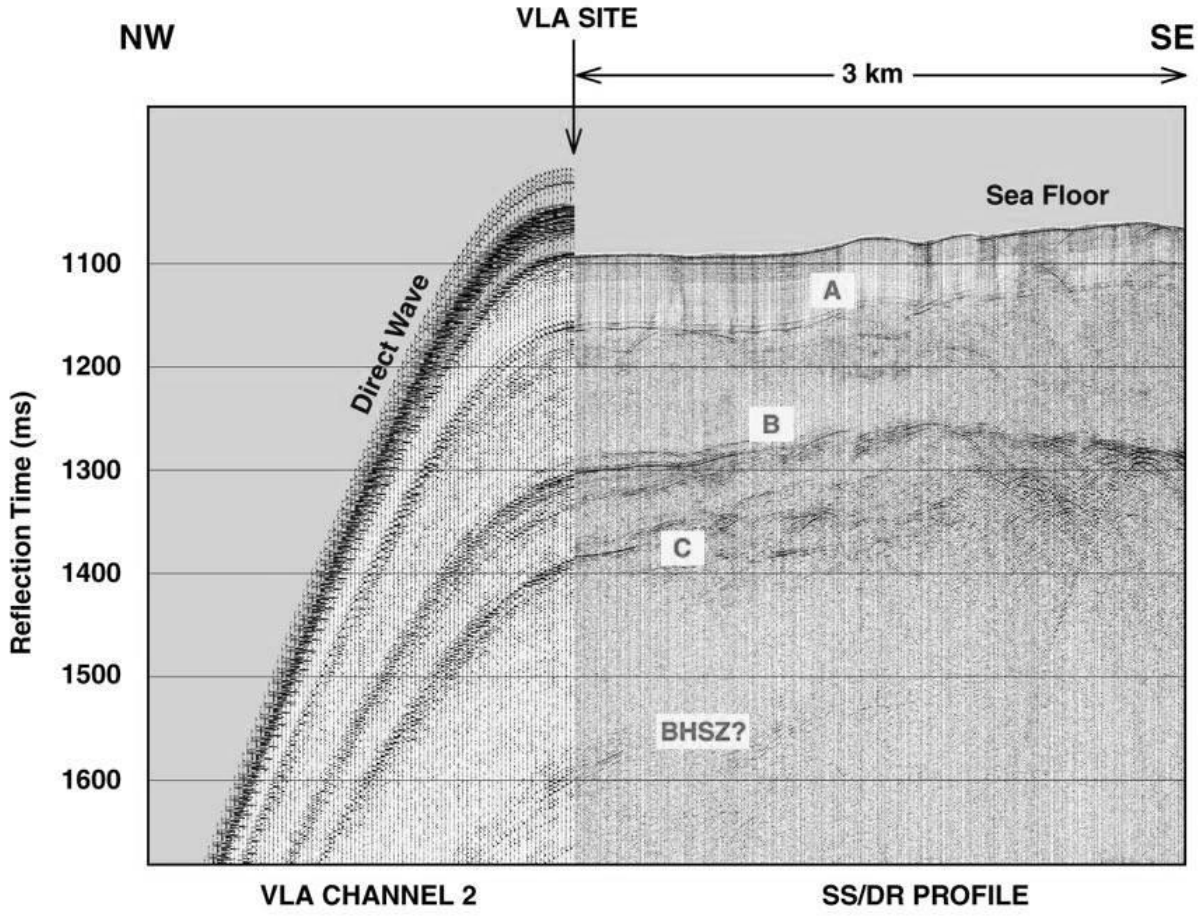

Comparison of VLA and SS/DR Data