Gas hydrate characterization from a 3D seismic dataset in the deepwater eastern Gulf of Mexico

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Abstract

Principal component analysis of spectral decomposition results combined with amplitude and frequency seismic attributes derived from 3D seismic data are used for the identification and characterization of gas hydrate deposits in the deepwater eastern Gulf of Mexico. In the central deepwater Gulf of Mexico (GoM), logging while drilling LWD data provided insight to the amplitude response of gas hydrate saturation in sands, which could be used to characterize complex gas hydrate deposits in other sandy deposits. In this study, a large 3D seismic data set from equivalent and distal Plio Pleistocene sandy channel deposits in the deepwater eastern Gulf of Mexico is screened for direct hydrocarbon indicators for gas hydrate saturated sands.

There has been no deepwater oil and gas exploration in the eastern GoM because of a long-standing oil and gas drilling moratorium. The nearest commercial oil and gas discovery to the study area is the Shell Jubilee Gas Field about 120 km to the west northwest where gas is being produced from upper Miocene high-density turbidites with a mass transport deposit top-seal. Sediments within the gas hydrate stability zone in the study area are similar in depositional style but are younger- Pleistocene. The nearest scientific drilling to the study area is at site 616 from ODP leg 96 where thick sandy facies were cored. Thick sequences of turbiditic frontal fan splays of the Mississippi channel and fan system are within the gas hydrate stability zone in the study area. The data show many meandering channels and channel lobes separated by mass transport complexes and inter-lobe clays. The thick Miocene to Pliocene channel fill in the deep eastern GoM basin has produced flat-lying sediments that have largely buried the deeper structures.

Whereas the central GoM has pervasive hydrocarbon migration structures caused by salt buoyancy displacing and piercing the sediments, similar vertical fluid migrations structures are far fewer in the eastern GoM. A basin-ward arcuate north-south trending deep-seated fault trend is, however, in the western part of the 3D study area. These faults extend from basement through the Cretaceous and penetrate into the thick Neogene fan deposits providing a conduit for fluid and gas migration into sandy reservoirs at the base of the gas hydrate stability field. Locally focused high amplitude anomalies, both peak-dominant and trough-dominant, are coincident with these localized vertical migration conduits. The velocity cube used for the time and depth migrations indicates a vertical low velocity field associated with the interpreted conduits for vertical fluid and gas migration. No bottom-simulating-reflector (BSR) is seen in the data, nor is there a BSR proxy such as an unambiguous depth to top-most free gas present. The seismic anomalies, however, suggest gas hydrate filled sands. High saturation gas hydrate sands are not interpreted to be pervasive in the area and are only interpreted above the deep- seated faults. Away from the faults, and without focused fluid migration, there are ample, thick, reservoir quality sands but without migration conduits to them, the sands within the gas hydrate stability zone are interpreted to be wet.

Seismic stratigraphic features where fluid migration forms gas hydrate targets are delineated using seismic stratigraphic principles. Principal component analysis of the band limited data at potential gas hydrate sands, and compared and calibrated with spectral decomposition thickness to constrain thickness in the absence of well control. Layers in the abyssal fan sediments are thinner than can be resolved with 50 Hz seismic and thus comprise composite thin-bed reflections. Amplitude vs frequency analysis are used to indicate gas and gas hydrate reflections. Synthetic seismic wedge models show that with 50Hz seismic data, a 40% saturation of a Plio Pleistocene GoM sand in the hydrate stability zone with no subjacent gas can produce a phase change (negative to positive) with a strong correlation between amplitude and hydrate saturation. The synthetic seismic response is more complicated if the gas hydrate filled sediments overlie gassy sediments. Hydrate (or gas) saturation in thin beds enhances the amplitude response and is used to estimate saturation. Gas hydrate saturation from rock physics, amplitude, and frequency analysis is compared to saturation derived from inversion at several interpreted gas hydrate accumulations in the eastern Gulf of Mexico.