Oil & Natural Gas Technology

DOE Award No.: DE-FE0009904

Quarterly Research Performance Progress Report (Period ending 3/31/2016)

Structural and Stratigraphic Controls on Methane Hydrate occurance and distribution: Gulf of Mexico, Walker Ridge 313 and Green Canyon 955

Project Period: 10/01/2012 – 07/31/2016

Submitted by:

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Signature

Office of Fossil Energy

Executive Summary

This quarterly progress summarizes the progress made towards Phase 1 which comprises the new OBS data processing and unified imaging of both MCS and new OBS data that are obtained from the USGS in Green Canyon 955.

Background

The overall objective is to identify and understand structural and stratigraphic controls on hydrate accumulation and distribution in leased blocks WR313 (WR: Walker Ridge) and GC955 (GC: Green Canyon) in the Gulf of Mexico using seismic and well data (Figure 1). The effort shall be completed in three phases – depth imaging, full waveform inversion and rock physics modeling. All three phases have been completed for the GC dataset. The results were insightful and answered some of the key question raised in the proposal. However, similar procedures did not give encouraging results with the WR dataset. It appears that the WR OBS dataset needed a better processing. The PI decided to test decomposing the OBS dataset into an upgoing and downgoing wavefield and inverted only the upgoing part of the wavefield. To test that the decomposition algorithm, PI decided to apply the procedure on the GC dataset. This report describes the application on the GC dataset.

Like in the in the first phase, the objective is to create a large-sale (resolution in the order of Fresnel zone) P-wave velocity model first using traveltime inversion and a corresponding depth image using pre-stack depth migration (PSDM). This task has been completed and some results are very promising. When the undecomposed dataset was being used, only 7 OBSs could be used for traveltime inversion due to poor signal-to-noise ratio. In this iteration 9 out of 10 OBSs that were deployed by the USGS could be used. Although velocity model in the previous effort was also smooth, it was not as informative as the model in this attempt. The unified imaging approach of jointly inverting MCS and OBS data is being described in this report.

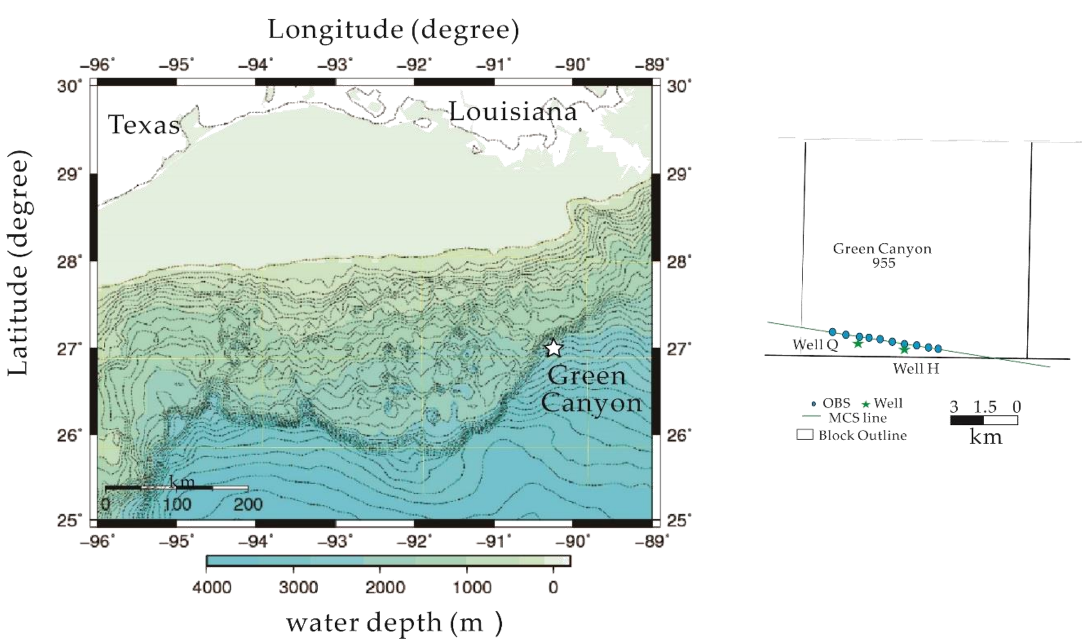


Figure 1. Base map. Location of the study area in the Gulf of Mexico. Location of the seismic line, wells and OBSs with respect to the block boundaries are shown in independent sketches.

Approach

Wavefield decomposition to separate the up- and downgoing parts can be understood as follows. Seismic events in OBS data comprise direct waves, primary reflections, source-side ghost, water-column reverberations, free-surface multiples and internal multiples. The recorded wavefields in OBS data can be divided into up- and downgoing parts according to the wave arrival directions. The downgoing wavefield contains the direct wave, receiver-side multiples and water-column reverberations, while the upgoing wavefiled includes all the primaries and source-side ghosts and internal multiples. Since the primary reflections are the main parts in our traveltime modeling, the upgoing wavefields are employed to attenuate the water-column reverberation and receiver-side multiples. Combination of the pressure and the vertical geophone (velocity) components results in the up- and downgoing wavefields. This is because pressure is a scalar quantity and up- and downgoing pressure wavefields get the same polarity on hydrophone recordings while the up- and downgoing pressure wavefields show opposite polarities on vertical geophone recording. Therefore, upgoing and downgoing wavefields can be separated as:

$$U = (P + \alpha Z)/2$$

$$D = (P - \alpha Z)/2,$$

where U is the upgoing wavefield, D is the downgoing wavefield, P is pressure as recorded on the hydrophone, Z is partical velocity recorded on the vertical geophone, α is a scalar (Grion et al., 2007). The wavefiled decompositions attenuates multiples and source reverberations but not bubble effects and swell noise (Figure 2). Nonetheless the overall data quality was better after wavefield decomposition. Predictive deconvolution and bandpass filter were also applied to the upgoing OBS wavefield to further improve data quality.

After the wavefield decomposition, all OBSs were located along the MCS profile. This step is important although the deployment location of each OBS at the sea surface is known. It difficult to determine its actual resting point on the seafloor due to a lack of knowledge of the under-currents. Uncertainly associated with OBS location may translate into errors in picking and model building. A simple and intuitive method for locating OBS along the MCS profile is adopted. First, presence of any remnant clock drift is checked from the symmetry of the near-offset (0 – 2km) direct arrivals which should have a parabolic trajectory under ideal conditions. Modeling of a symmetric set of direct arrivals for all OBS also provided an average value of the ocean water velocity (1.49 km/s) to be used in the rest of the model building. It is notable that in this case study, a large fraction of each raypath is in the water column. Following water velocity estimation, the entire MCS dataset is depth-migrated at the water velocity with the understanding that other than the seafloor, no horizon will be correctly positioned in the migrated stack. After obtaining a confident estimate of the ocean water velocity, the MCS data are depth migrated using the stacking velocity model. This image is interpreted to generate the initial structural framework for velocity-depth inversion (see below). Next, using the water velocity and depth-migrated seafloor structure, the location of individual OBSs along the seafloor is estimated in a trial-and-error manner. Finally, the positions of OBS are verified with each other to reach a criterion that all shot positions should be consistent.

Velocity model for migration of the MCS data were generating though inversion using an approach known as Unified Imaging (UI), which was developed by Jaiswal and Zelt (2008) as a way of testing the Deragowski principle, i.e, the consistency of a velocity model with its corresponding depth migrated image. The application of UI to the GC and WR data were done as follows. First, 4 key horizons GC955 (SF, B1 – 3; Figure 3b) were interpreted in the stacked data. The horizons were selected based on their clarity and geological sensibility. In both datasets the shallowest horizon was the seafloor and the deepest horizon was below the zone of interest. Next the OBS and the MCS stack were merged (Jaiswal et. al, 2006) for identifying the reflections from horizons in the stacked data at larger offsets (Figures 4). The OBS and MCS traveltime picks in were inverted jointly in a layer-stripping manner (Zelt and Smith, 1992) to develop a layered velocity model for GC955 datasets. In the inversion, the zero-offset raypaths constrained the reflector geometry (Figure 6) while the wide-angle raypaths constrained the velocity model (Figure 7). To ensure that the velocity model is fit for depth migration, no velocity jumps were allowed across the model boundaries. The inversion was halted when the MCS traveltime misfits were within 2ms and OBS traveltime misfits were within 5ms, which are the respective sampling intervals. To ensure that the overall velocity is kinematically correct, they were used for depth migration of their respective datasets (Figure 8). The geometry of the interfaces in the migrated images were compared with the geometry of the interfaces from the joint MCS-OBS inversion; a good correspondence (Figure 8b) confirmed that the inversion velocities are reasonable.

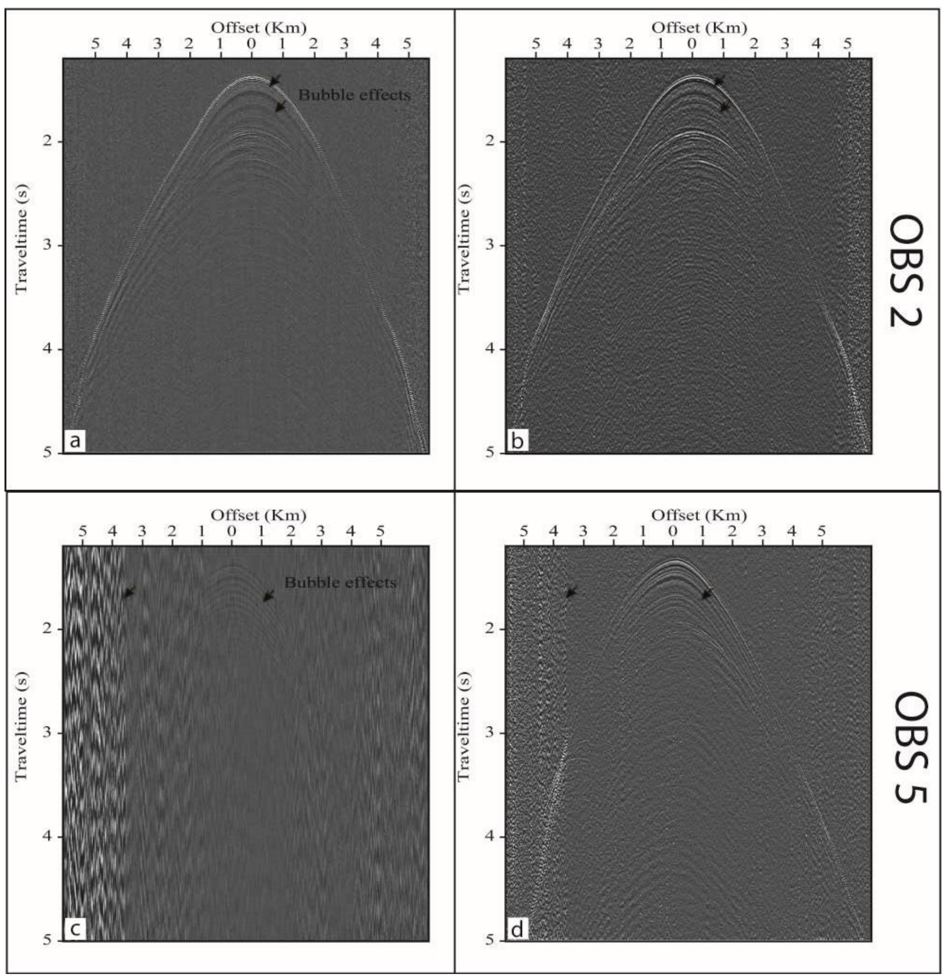


Figure 2. The OBS data. The left columns show the upgoing wavefileds after decomposition. The right columns display the data after predictive deconvolution and bandpass filter. These data after denoising are used to pick traveltimes for inversion.

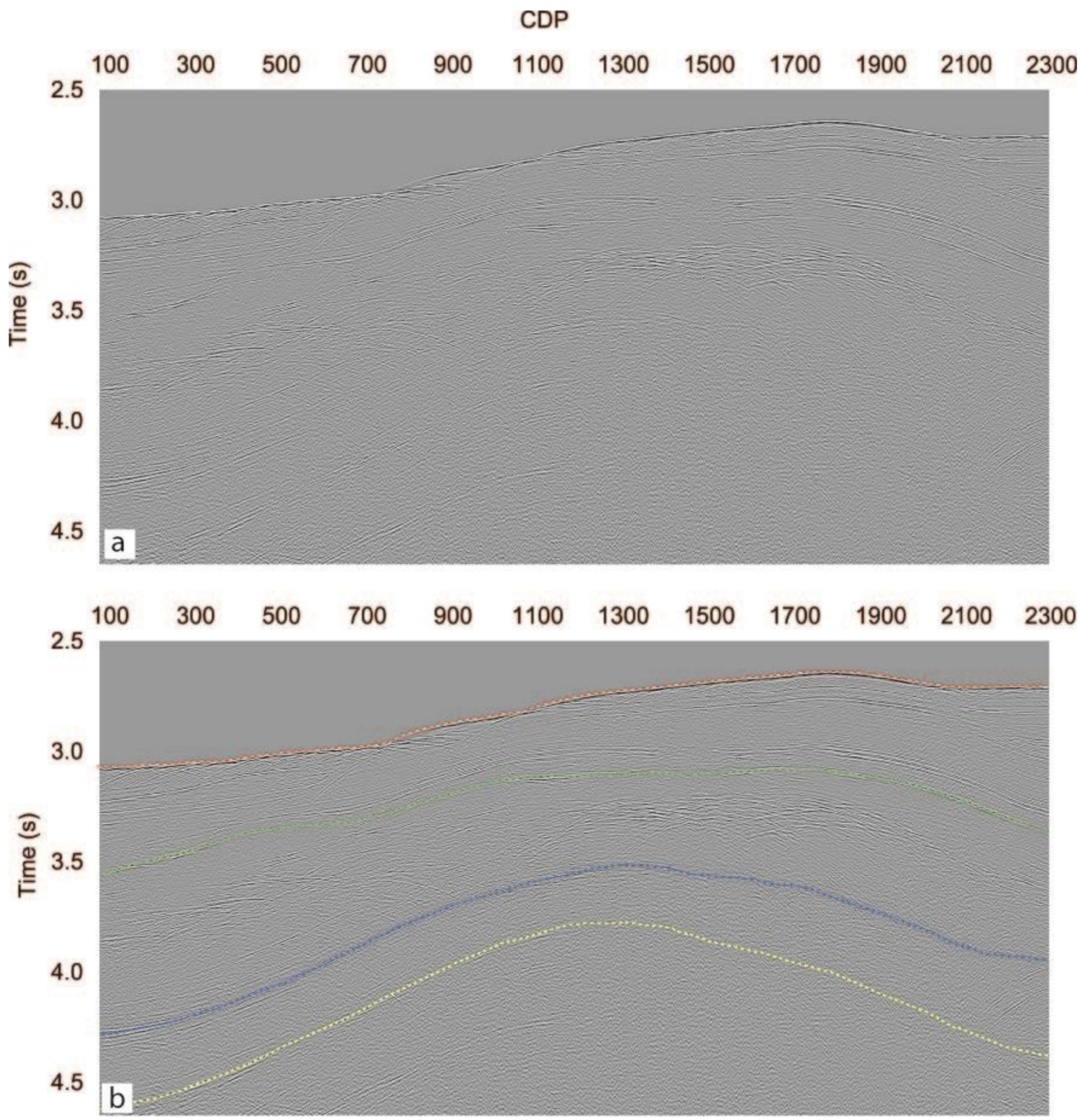


Figure 3. GC 955 Stack. (a) MCS data stacked with velocity model obtained from inversion (b) Same as a. with four horizons, SF and B1 – 3, used in inversion interpreted. SF is the seafloor and B1-4 (red, green, blue and yellow) are generic horizons that are identifiable though the entire expanse of the stacked data. The zone of interest is between B1 (green) and B2 (blue).

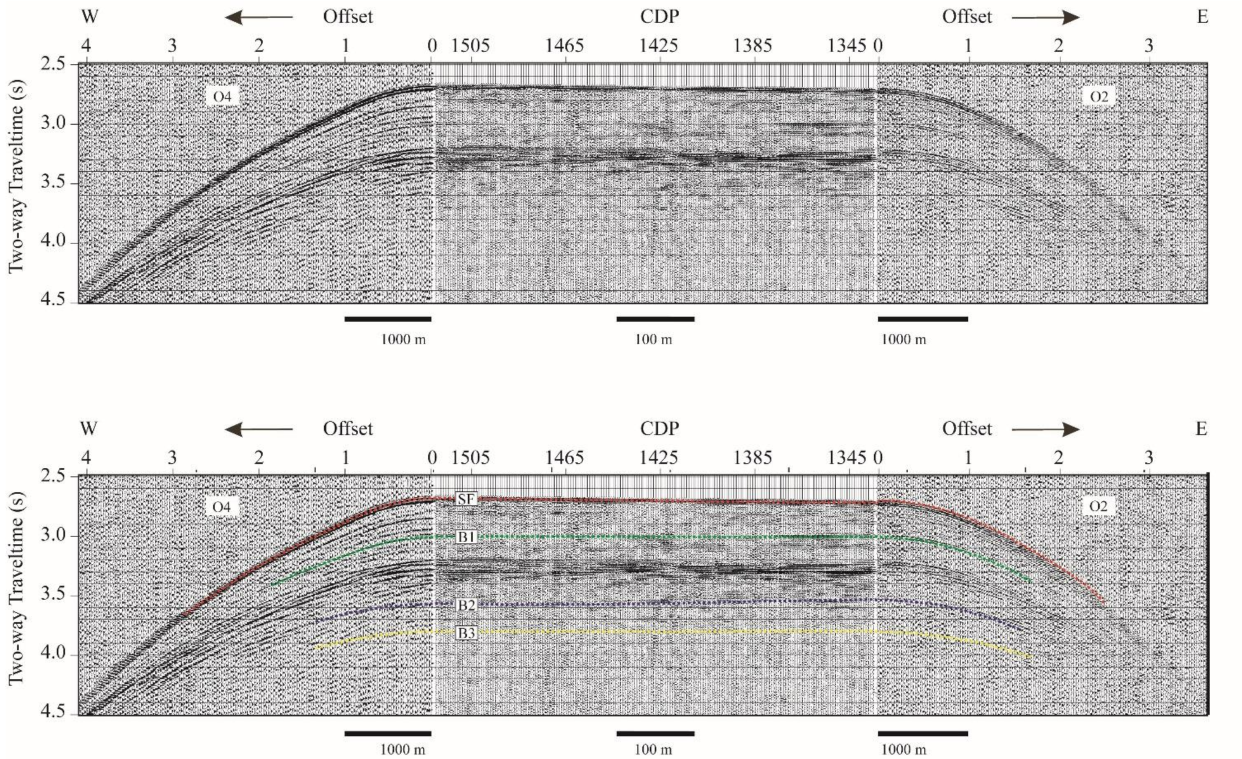


Figure 4. GC 955 Data merge. Above: OBSs 2 and 5 are merged with MCS data based on the seafloor and general reflection character of the sub-seafloor coda. Below: Reflections nomenclature and colors have the same meaning as in Figure 3.

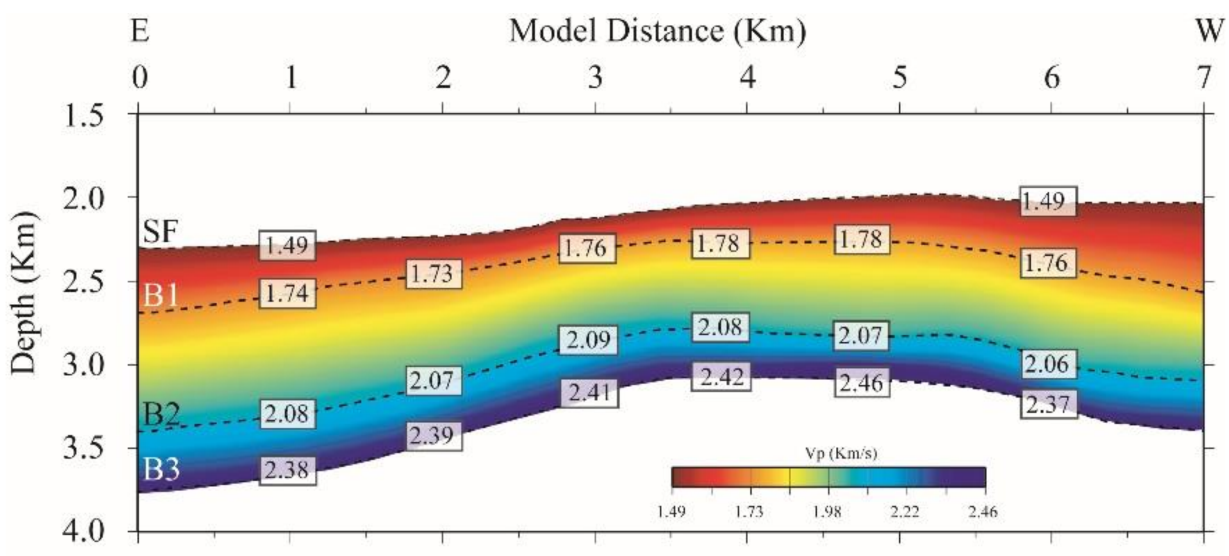


Figure 5. GC 955 model. P-wave velocity from joint inversion of OBS and MCS traveltimes. Modeling is done such that there is no velocity discontinuity across any interface. Velocity values along the interfaces are labeled.

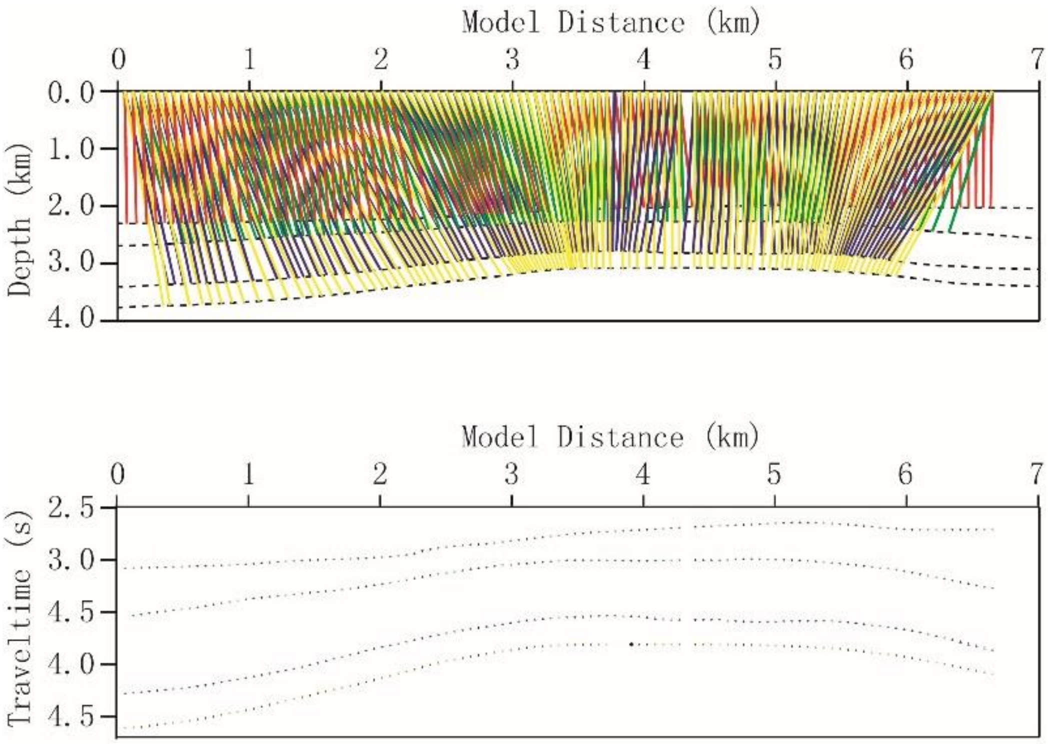


Figure 6. GC955 MCS traveltime modeling. Upper panel shows Ray Paths and lower panel display traveltime fits. The overall prediction misfit is 2ms, the data sampling interval.

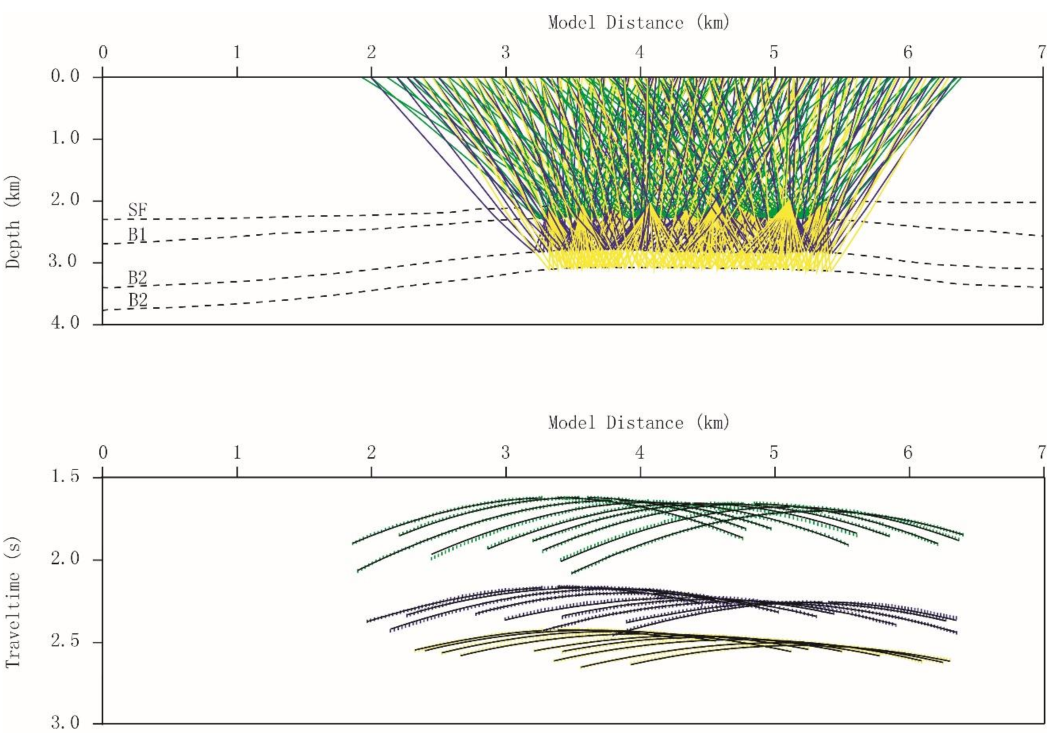
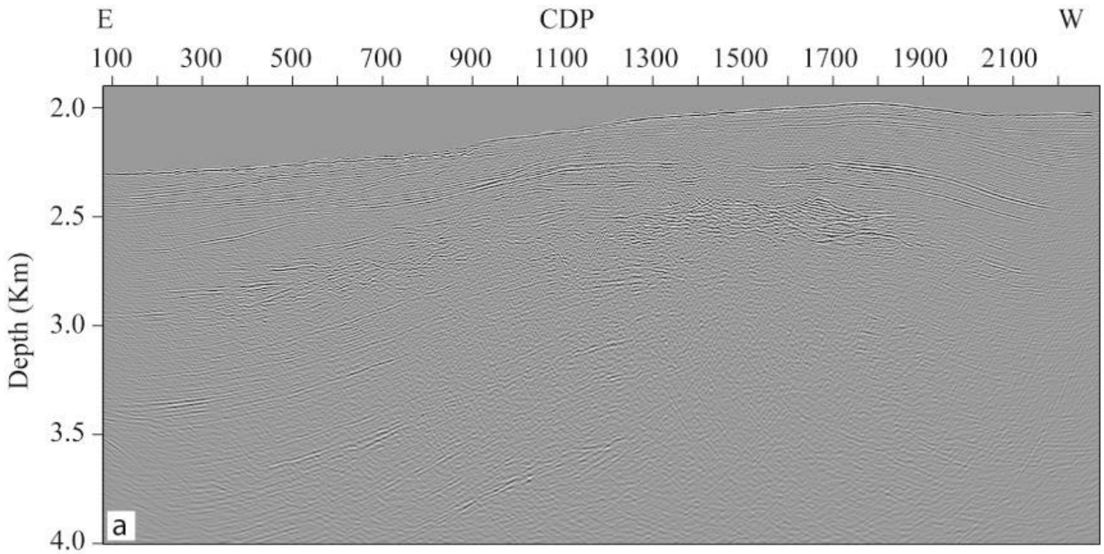


Figure 7.GC955 OBS traveltime modeling. Upper panel shows Ray Paths and lower panel display traveltime fits. The overall prediction misfit is 2ms, the data sampling interval.



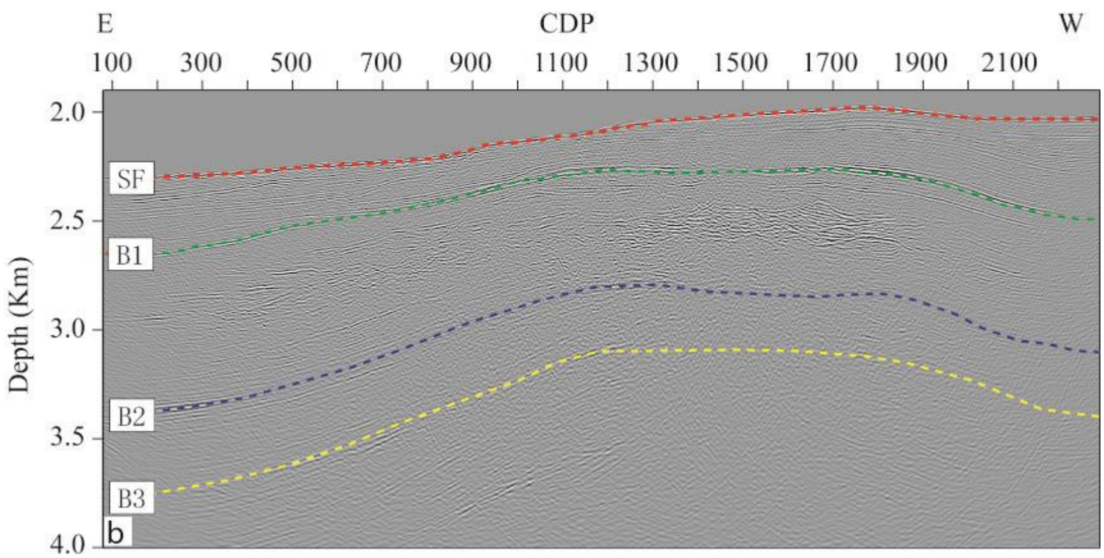


Figure 8. GC 955 Depth Image. (a) Data migrated with velocity model obtained from traveltime inversion (b) Same as a. with four horizons, SF and B1 – 3, from the model in Figure 8. Labels have the same meaning as in Figure 4. The success of this inversion-migration approach is from the fact that the migrated interfaces agree very well with their corresponding inverted counterparts. The OBS are labeled and their locations are indicated with a solid dot.

Results

Decomposed of OBS gathers into upgoing and downgoing wavefield led attenuation the multiples and water-column reverberations and increased the overall signal-to-noise ratio of the data. Using the upgoing wavefields of 9 OBS for traveltime inversion, a smooth velocity model with reasonable velocity structure was obtained. The velocity model resulted in a reasonable depth section along the MCS profile. Full waveform inversion is going to apply to the new datasets trying to get more detailed information about the hydrate-bearing shale and sands.

Conclusions

The new OBS data offered by USGS has adequate temporal and spatial resolution for serving the purposed of this proposal. The new data have larger offsets than the data used last time. The wavefield decomposition could attenuate multiples to certain level. The new data are expected to use in full waveform inversion to in the next phase.

References:

Grion, S., R. Exley, M. Manin, X. Miao, A. Pica, Y.Wang, P.,Granger, and S. Ronen, 2007, Mirror imaging of OBS data:First Break, 25, 37–42.

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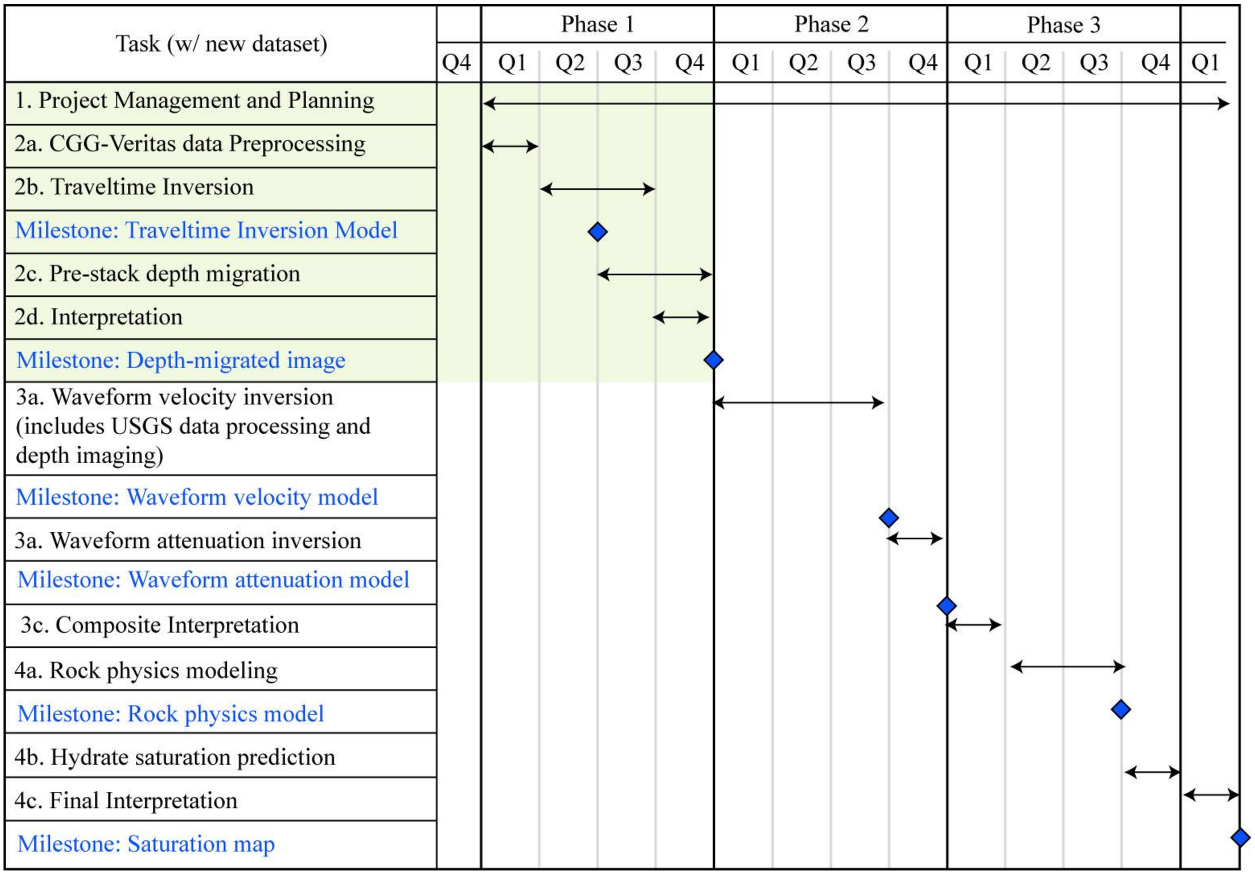
Project milestone chart



The project is on target till date. Tasks already completed in the milestone chart are shaded in green.

Milestone Status:

With newly processed dataset

Milestone	Description	Status	Schedule
Traveltime Inversion Model	The recipient shall compare the real and predicted reflection traveltimes from the final velocity model to be used for PSDM.	Done for CGGVeritas Datase and for the USGS dataset	Completed on target
Depth Migrated Image	The recipient shall compare structure and stratigraphy between the final depth image and images in literature and SSRs.	Done	Completed on target
Waveform velocity model	The recipient shall compare waveform inversion velocity and sonic logs at well locations.	Ongoing	On target
Waveform attenuation model	The recipient shall compare real and synthetic simulated data.	Ongoing	On target
Rock physics model	The recipient shall compare predicted hydrate saturation at well locations with that available in the literature and methods of other DOE funded PIs, if available.	Ongoing	On target
Saturation map	The recipient shall compare consistency between hydrate distribution and structural/stratigraphic features interpreted in the study area.	Ongoing	On target

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