Oil & Natural Gas Technology

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Quarterly Research Performance Progress Report (Period ending 9/30/2015)

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

Project Period: 10/01/2012 – 09/30/2015

Submitted by:

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Signature

Office of Fossil Energy

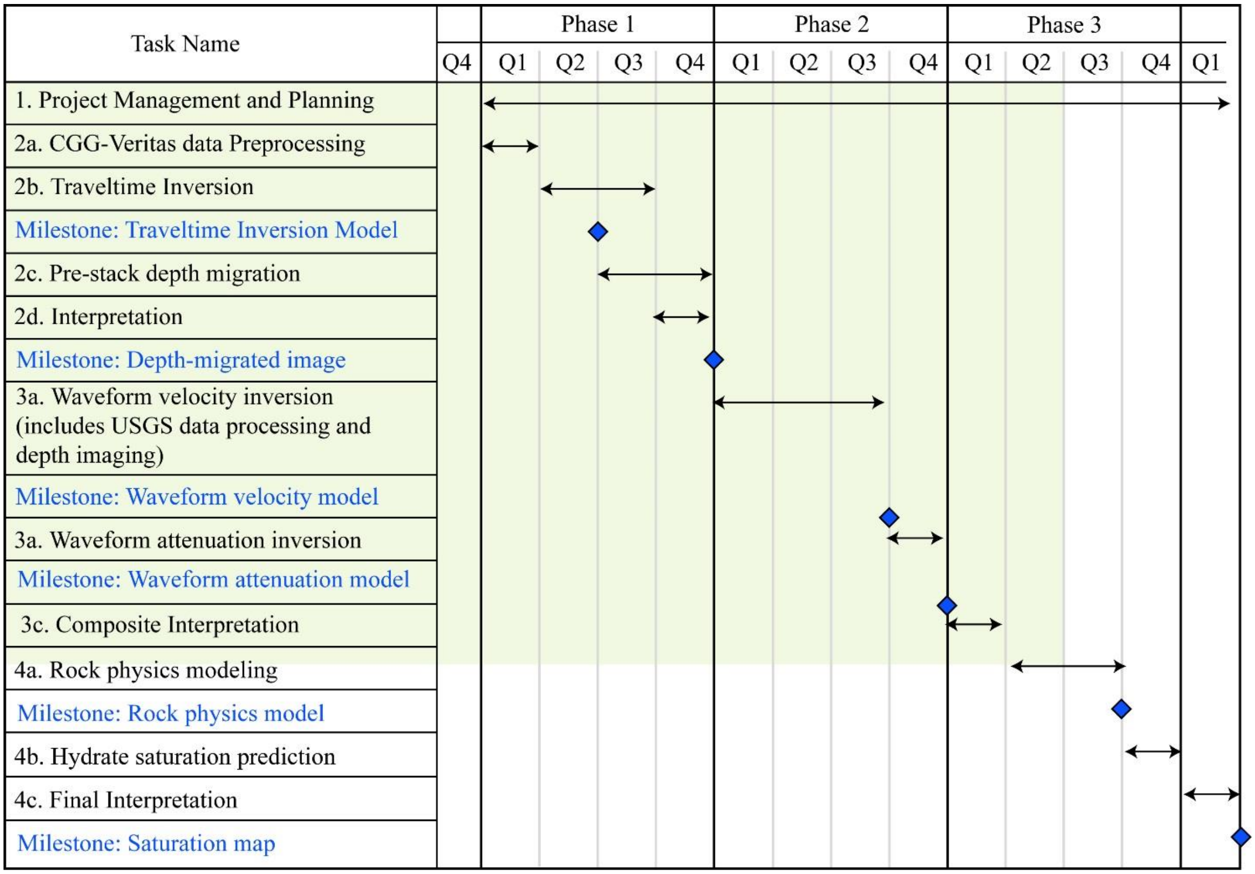

Table 1. Gantt chart. The project is on target till date. Tasks already completed in the milestone chart are shaded in green.

Executive Summary

This quarterly progress summarizes the progress made towards completion of Phases 2 and 3which comprises traveltime and waveform inversion of WR313 data.

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 is to be completed in three phases. In the first phase, the objective is to create a large-sale (resolution in the order of Fresnel zone) P-wave velocity model using traveltime inversion and a corresponding depth image using pre-stack depth migration (PSDM). This phase was completed in due time. In the second phase, the objective was to jointly interpret the pre-stack depth migrated images and the full-waveform V_P models that were obtained as Phase 1 and Phase 2 deliverables. This phase was also completed in due time and a manuscript summarizing the efforts up till Phase 2 for GC955 was communicated to Journal of Geophysical Research – Solid Earth. The papers are currently under revisions. The third phase has two objectives. The first objective is to create a hydrate distribution map with the help of P-wave velocity and attenuation model created in the second phase and standard rock physics modeling method. This part of the work for GC955-H well has been complete in time. So far we have been having difficulty in repeating FWI for WR313 dataset. We have reprocessed WR313 OBS data and restarted the whole modeling exercise. This report describes the progress made towards modeling the WR313 dataset.

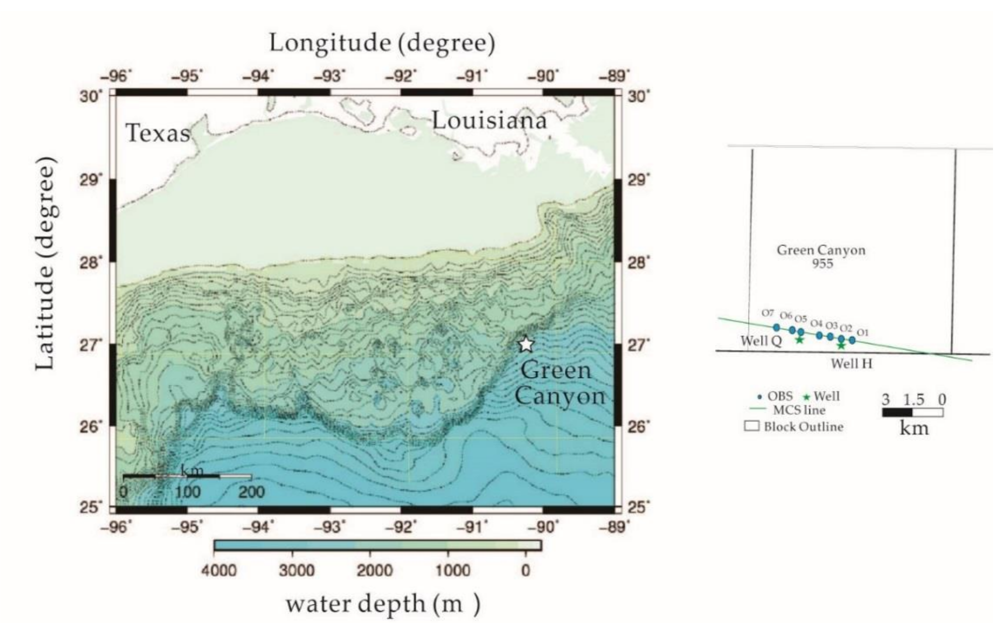

Figure 1: Base map. Seafloor bathymetry of Gulf of Mexico showing the location of the study area at the mouth of Green Canyon. The acquisition layout within lease block Green Canyon 955 (GC955) is shown in the inset. Solid line is the track of the multi-channel seismic (MCS) profile. Solid circles are location of ocean bottom seismometers (OBS) O1 – O7. Solid stars mark the locations of the wells Q and H that were drilling during the Joint Industry Project Leg II (JIP II).

Approach

Both OBS and MCS data, obtained from USGS, were set up for processing in ProMAX© processing software using the navigation data made available from the field (Figure 1). After setting up the navigation, the data were imported into and visually verified for their correctness. Following this, bad traces were selectively removed and the remaining dataset was processed to enhance the signal-to-noise ratio. The processing made significant improvements in the quality of the OBS data (Figures 2). The MCS data were assembled into CMP domain where velocity analysis was conducted. Finally, a stack was created (Figure 3). The stacked data were then depth migrated and verified with the well depths.

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 WR data were done as follows. First, key horizons (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 (Figure 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 WR (Figure 5) datasets. In the inversion, the zero-offset raypaths (Figure 6a) constrained the reflector geometry while the wide-angle raypaths (Figure 6c) constrained the velocity model. 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 (Figure 6b) and OBS traveltime misfits were within 5ms (Figure 6d), which are the respective sampling intervals. To further ensure that the velocity model is accurate, the velocity profiles were compared with the Well Vp (Figure 5) blocks. To ensure that the overall velocity is kinematically correct, they were used for depth migration (Figure 7a). 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 7b) confirmed that the inversion velocities are reasonable.

The data statistics used in the inversion are as follows:

WR313

	Stack	OBS
Seafloor	100	1794
H1 (Green, all figs)	100	1164
H2 (Blue, all figs)	100	1152
H3 (Yellow, all figs)	95	1212

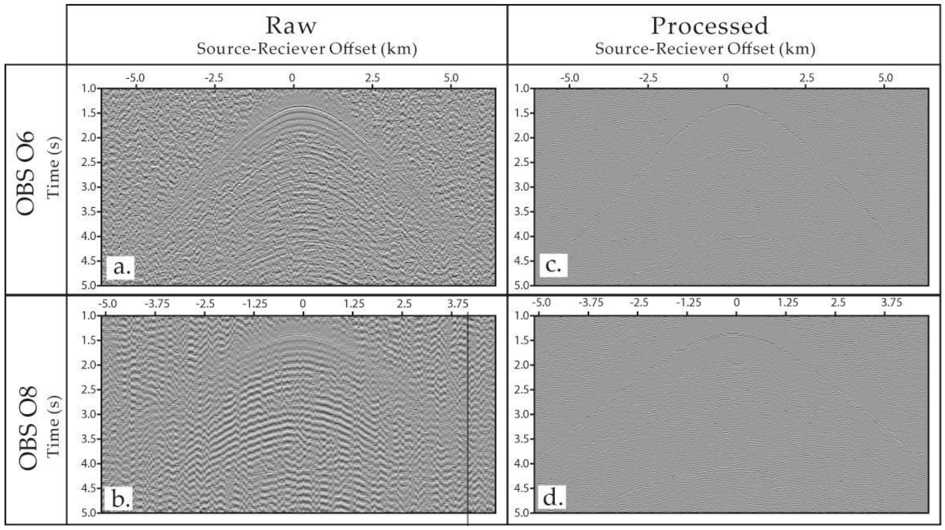

Figure 2. OBS data. a) and b) are the raw data quality display from the OBSs O6 and O8 in block WR 313. c) and d) and the same data after processing, which includes filtering and deconvolution.

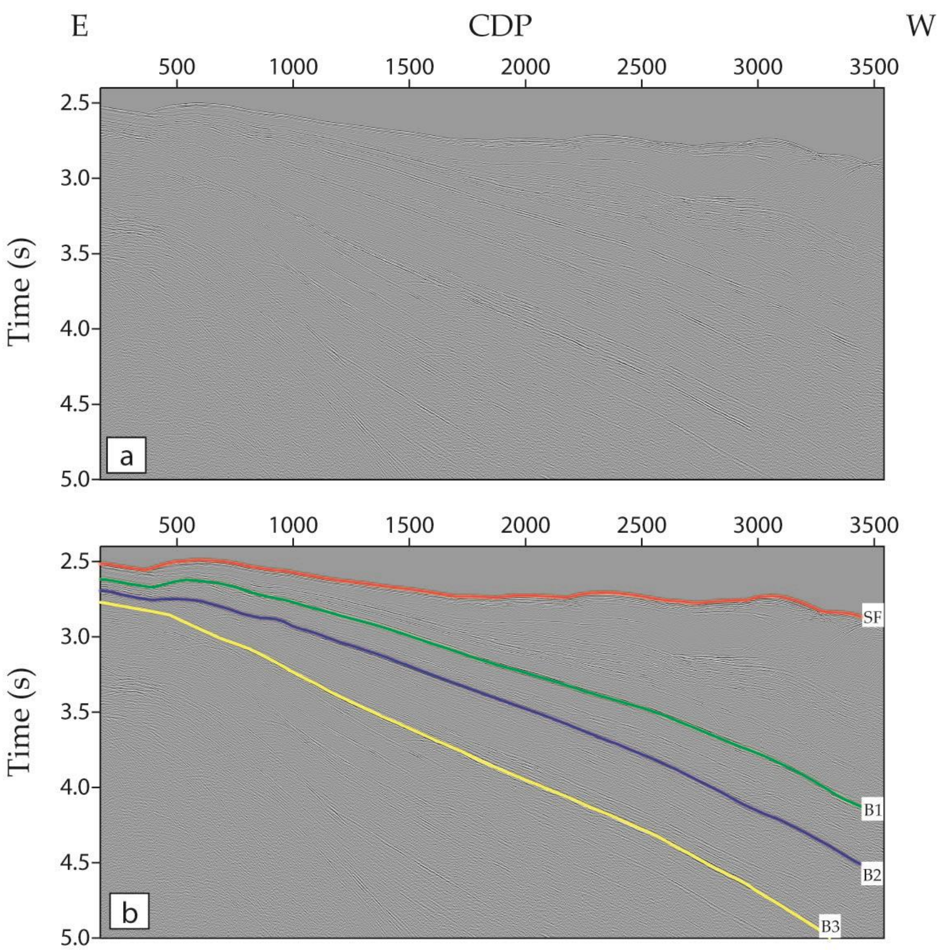

Figure 3. WR 313 Stack. (a) MCS data stacked with velocity model obtained from inversion (b) Same as a. with four horizons, SF and B1 – 3, used in inversion interpreted. SF is the seafloor and B1-4 are generic horizons that are identifiable though the entire expanse of the stacked data.

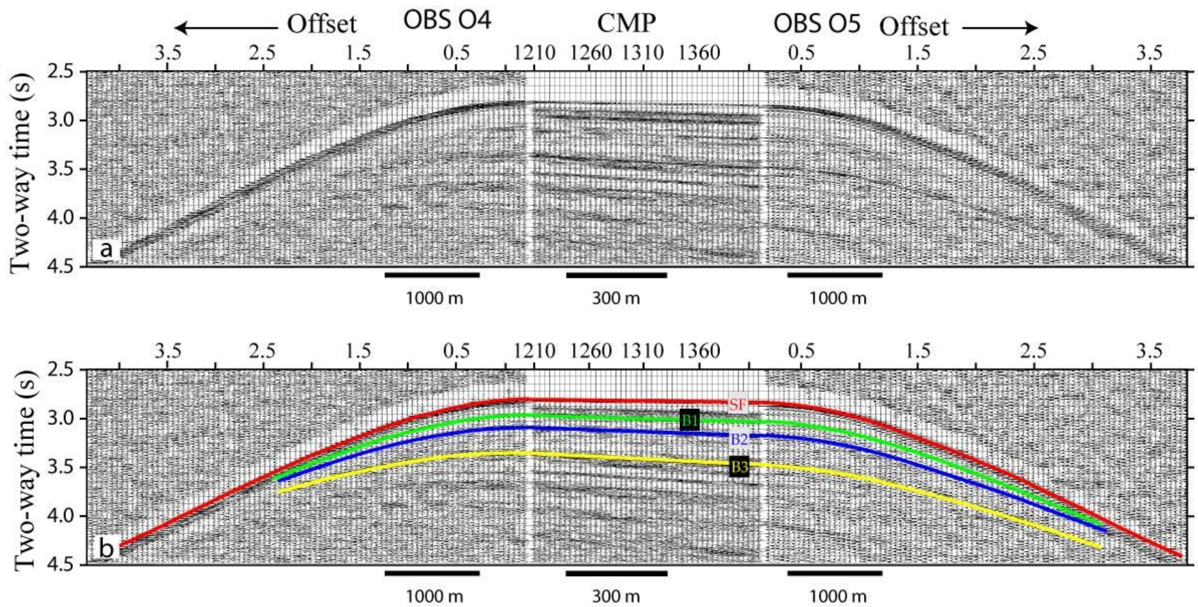

Figure 4. WR 313 Data merge. a) OBSs O4 and O5 are merged with the MCS data according to the seafloor and general reflection character of the sub-seafloor coda. (b) Reflections nomenclature and colors have the same meaning as in Figure 5.

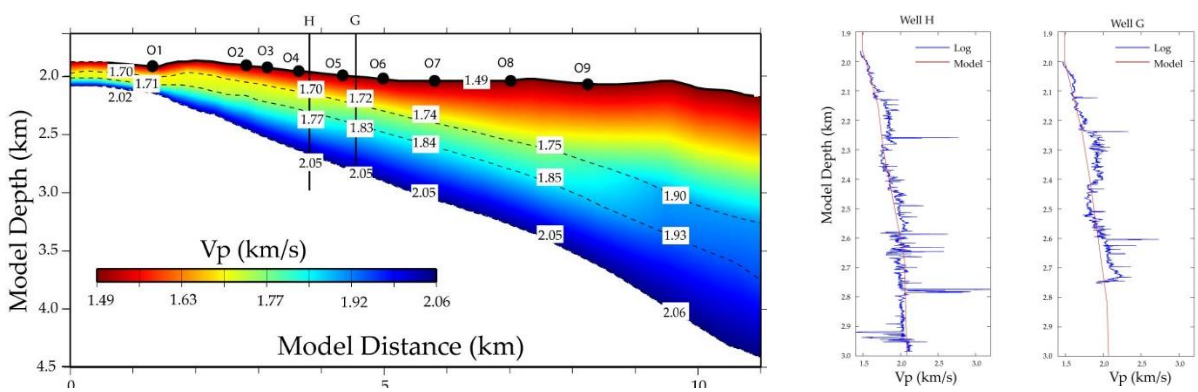

Figure 5. WR 313 model. a) P-wave velocity from joint inversion of OBS and MCS traveltimes. The OBS and well locations are labeled. Modeling is done such that there is no velocity discontinuity across any interface. Velocity values along the interfaces are labeled. The comparison of velocity from inversion with wells are shown in (b) for Well H and (c) for Well G. The traveltime inversion is able to predict the background velocity trend as expected.

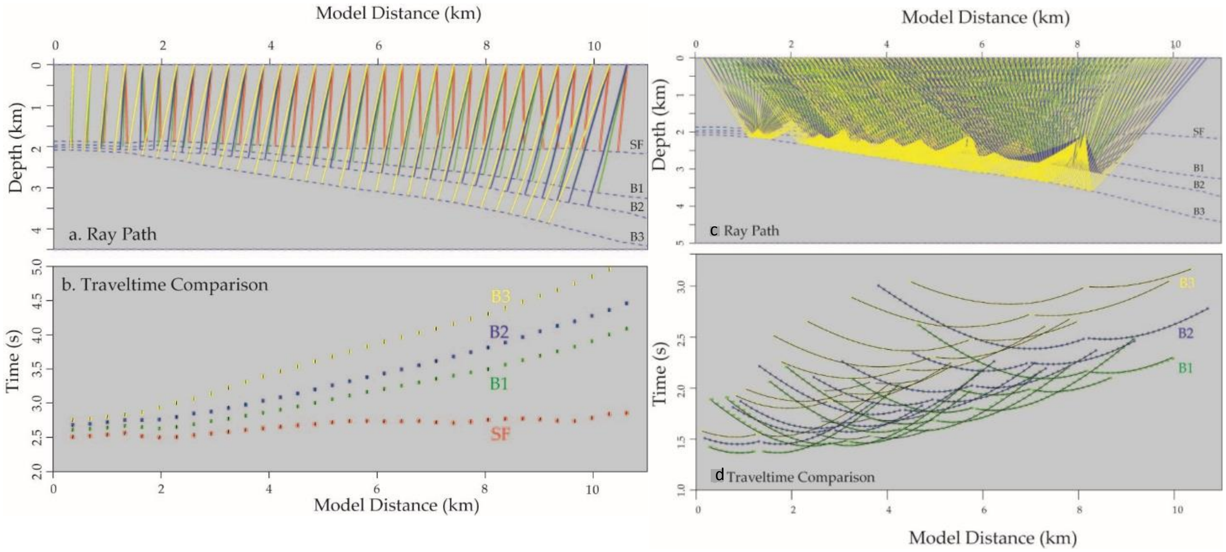

Figure 6. WR 313 MCS traveltime modeling. For clarity, every 2nd shot is shown. a) Ray Paths b) traveltime fit. The overall prediction misfit is 2ms, the data sampling interval. WR 313 OBS traveltime modeling. c) Ray Paths. For clarity every 2nd ray is displayed. d) traveltime fit. In (a) - (d) labels and colors have the same meaning as in the previous figures. The overall prediction misfit is 5ms, which is the sample interval.

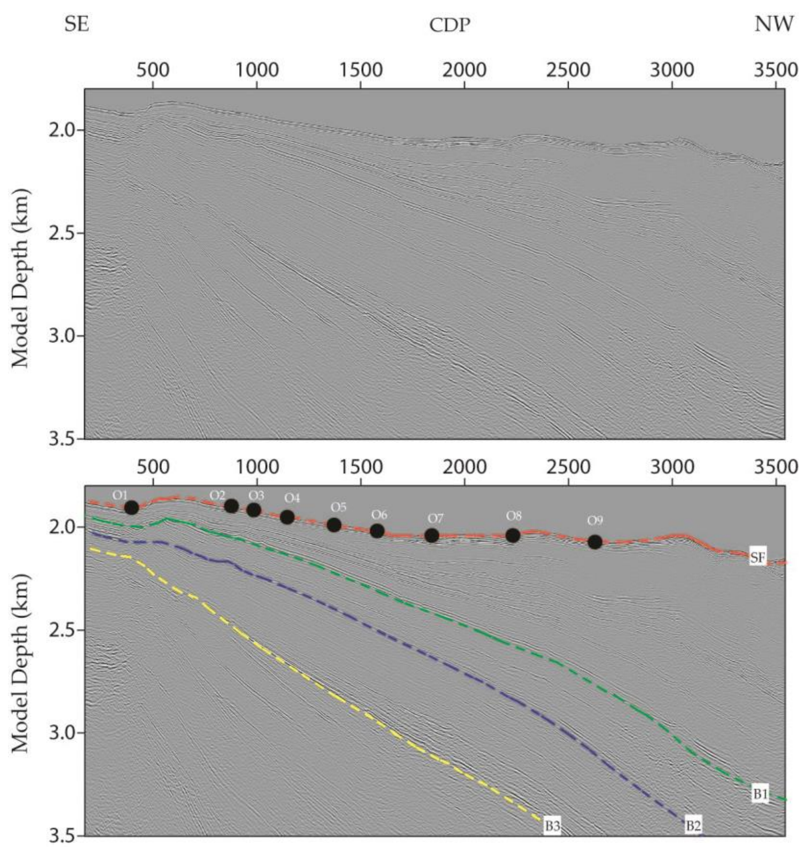

Figure 7. WR 313 Depth Image. (a) Data migrated with velocity model obtained from traveltime inversion (b) Same as a. with four horizons, SF and B1 – 3, from the model in Figure 5. Labels have the same meaning as in previous figures.

Results:

The traveltime inversion is only able to predict the background trend of the logs, which is as expected. Traveltime inversion can only achieve resolution of a Fresnel's zone which is about ~150m in this case. By using reflections from multiple horizons we have been able to achieve better resolution (50 – 75 m) but not enough to explain all features of the log. We expect that the log velocity will be better explained by full waveform inversion which is to be conducted in the next phase.

Conclusions:

The 2-D data acquired by the USGS has adequate temporal and spatial resolution for serving the purposes of this proposal. The WR313 data are less noisy than GC955 data. Similarly approach to inversion and migration could be applied to both datasets to obtain depth images that are in-line with published geology from both sites. The depth images from both the sites appear to be consistent with the well logs in terms of a basic litho-stratigraphic description of the locations and velocity trends, indicating that the velocity models from traveltime inversion are good approximation of the geology and should be fit for serving as starting model for full waveform inversion.

Milestone Status:

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.	Done	Completed On target
Waveform attenuation model	The recipient shall compare real and synthetic simulated data.	Done	Completed On target
Rock physics model	The recipient shall compare predicted hydrate saturation at	Ongoing	On target

	well locations with that available in the literature and methods of other DOE funded PIs, if available.		
Saturation map	The recipient shall compare consistency between hydrate distribution and structural/stratigraphic features interpreted in the study area.	Ongoing	On target

References:

Jaiswal, P., Zelt, C.A., 2008. Unified imaging of multichannel seismic data: Combining traveltime inversion and prestack depth migration. Geophysics 73, VE269-VE280.

Jaiswal, P., Zelt, C.A., Pecher, I.A., 2006. Seismic characterization of a gas hydrate system in the Gulf of Mexico using wide-aperture data. Geophysical Journal International 165, 108-120.

Zelt, C.A., Smith, R.B., 1992. Seismic traveltime inversion for 2-D crustal velocity structure. Geophysical Journal International 108, 16-34.

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