[PS]Offshore Peru, Trujillo Basin, Block Z-46: 2D PSTM Seismic Processing Reveals Deep Basins, Normal and Trans-Tensional Faulting, and Thick Eocene/Oligocene Stratigraphically Complex Submarine Fans Linked to Evidence of Hydrocarbons/DHIs*

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Abstract

Reprocessing (2009) of 5684 line km of 1993/1996 era 2D seismic from the Peru Trujillo Basin, using advanced pre-stack multiple removal and Kirchoff curved ray PSTM (Pre-Stack Time Migration), shows Lower Cretaceous to Early Tertiary (Eocene, Oligocene and Lower Miocene) deep basins in detail not previously interpretable using the original data. Block Z-46 contains only a few wells drilled before 1999, testing subsurface highs found in 300-400 meters of water. New seismic reprocessing reveals that wells in the southern part of the block were drilled on "bald" Paleozoic basement horsts. Reprocessed seismic shows extensive Eocene and Oligocene submarine fans present downdip in fault-bounded closures, and in stratigraphic pinchouts.

3D visualization of the 2D data reveals that the probable entrance point of early Tertiary deposition in the south part of Block Z-46 occurred through erosion of a zone of weakness in the adjoining Salaverry Basin near the coastline of Peru. The 2D data also shows that the Block Z-46 has secondary Tertiary-age wrench faults that deform early normal faulting of the deep horsts and grabens. The presentation is illustrated with 2D seismic examples showing untested Tertiary trap concepts; shingled, stacked submarine fans, and suggests that local faulting is complex enough to require more seismic shooting to resolve mapping geometries.

Introduction

During this G&G study (2008-2009) SK Energy reprocessed 5684 line km of 1990's vintage 2D data from field tapes using prestack time processing services of 3DGeo (now FusionGeo) in Houston, Texas. Figure 1 shows a map of the location of Block Z-46 offshore Peru and a regional stratigraphic column. SK Energy has done a comprehensive study of onshore geology and used all available 2D seismic to connect the onshore to the offshore geology. The company has also completed airborne aeromagnetic mapping and coastal geological field work. Water depths in Block Z-46 range from 300 m to 2000 m.

The Trujillo Basin has source, reservoir and seal components in common with the petroleum system of the Talara Basin to the north. The predicted Trujillo Basin oil source rock is the Upper Cretaceous Redondo Formation which sources Paleozoic, Cretaceous, Paleocene and Eocene sands in the Talara Basin. The Talara Basin has produced 1.9 billion bbls and 1.9 TCF gas from Paleozoic and Tertiary reservoirs; however, the Trujillo Basin has only oil shows and has no established production. The conclusion of this paper, after working with the reprocessed seismic, is that there are indications of thick sand reservoirs away from the bald highs, and deep basins may be have Cretaceous source rocks.

Key Regional Features

The Trujillo Basin is underlain by continental crust and is unusual because the basin sits in a convergent margin deformed by Miocene-age strike slip tectonics. The original setting of the Trujillo Basin included normal, extensional faults during the Paleozoic and Mesozoic (Ghazi and Emmet, 2004; PARSEP, 2001). Miocene-age strike-slip faulting has moved terrain up against the eastern part of the Trujillo Basin so that the Salaverry Basin has a suture zone that can be interpreted on the east side of Block Z-46.

Figure 2 shows a typical west to east 2D seismic line and interpreted stratigraphic ages of key seismic reflectors. A key seismic marker is a "hard" peak known at the Lower Cretaceous Unconformity. This regional marker is present in both the Trujillo and Salaverry basins and also in onshore outcrops. Upper Cretaceous, Lower and Middle Eocene are interpreted to be truncated by this unconformity, marked in magenta on Figure 2.

Block Z-46 contains several deformed linear basins, including the northern Leon Basin and southern Morsa Basin. Part of this study was to map the normal and wrench faults seen on the reprocessed 2D seismic. A tectonic map (Figure 3) shows that normal faults in the Tertiary cover have been tectonically deformed after normal, extensional movement by regional wrenching caused by Tertiary-age subduction of the Nazca and Pacific plates beneath the South American plate. The early horst and graben normal faults have sheared in a right lateral sense, and the original basins have been squashed and twisted.

The wells drilled in the Trujillo Basin so far have targeted present day shallow water depths, and large anticlinal structures, but the wells did not find many thick sand reservoirs (PARSEP report, 2001). The most interesting well is the Repsol Morsa-1X (1998, TD 1281 m) which tested Tertiary sediments on a horst structure and found oil shows in the Eocene. A well cross-section (Figure 4) from the south (left) to the north (right) shows the four wells drilled in the Trujillo Basin. The middle of the cross-section shows seismically mapped, but undrilled, Eocene/Oligocene age horizons with reservoir potential in Block Z-46. An important reservoir data point is the Oxy Delfin #1 (1971, TD: 2735m). The Delfin-1 found about 30.4 meters of wet, but fairly clean and porous (18-24% porosity) Lower Eocene sands, which have been correlated seismically to a massive deepwater fan package in a prospect area in the Morsa Basin area.

Seismic PSTM Reprocessing

The PSTM seismic reprocessing project included 5684 kilometers of 1993 and 1996 vintage data shot by previous operators. Other legacy 2D data was also included in the seismic regional interpretation. 3DGeo (Houston, Texas) reprocessed the study data in 2008-2009. The reprocessing met two challenges: enhancing signal to noise in the deep section below 1-1.5 seconds time, and removing water bottom multiples.

Velocities for PSTM migration were picked every 1000 m on each line using an automatic velocity picking routine, plus professional QC by 3DGeo processors. Deconvolution was effective in removing water-bottom multiples, and radon removed the short period multiples. The final pre-stack time Kirchoff migration was very successful. AGC time variant scaling made a big difference in imaging the deep section. The improvement of the data above and below the Lower Cretaceous unconformity was dramatic (Figure 5) and forced interpreters to take a completely new look at the Morsa Basin area in the south end of Block Z-46.

Results

Reprocessed PSTM 2D seismic shows extensive Eocene and Oligocene submarine fans present in fault-bounded closures, and in stratigraphic pinchouts. We think these are slope and deepwater fans as evidenced by onlap and downlap morphology. The postulated sand-prone facies are higher amplitude (brighter) than the overlying shale facies. One prospect idea for Block Z-46 is a stratigraphic oil trap downdip of the Morsa 1X well. The Eocene structure map, and dip and strike lines are shown in Figure 6.

A time structure map of the Lower Cretaceous in the Salaverry Basin and the Trujillo Basin revealed a notch which could be an entry point for Lower Eocene, Middle Eocene and Oligocene submarine fans. A strike oriented north-south PSTM line showed a wrench fault that created a zone of weakness in the Lower Cretaceous. A submarine canyon incised into the Lower Cretaceous in the Early Tertiary funneling sand toward the basin. Figure 7 is a map of this canyon and a 3D visualization snap shot of the notch point and resulting Eocene submarine fan deposit in Block Z-46.

Conclusions

Reprocessing the 2D seismic, 1) discovered potential source-rich deep Cretaceous basins and Eocene sand-prone facies in the offshore that were not previously recognized, 2) enabled a more detailed tectonic map of faults across the basin, and 3) and imaged Lower Eocene stratigraphic pinchouts, and faulted bounded closures as potential undrilled hydrocarbon accumulations in Block Z-46. More seismic shooting is required to resolve mapping geometries.

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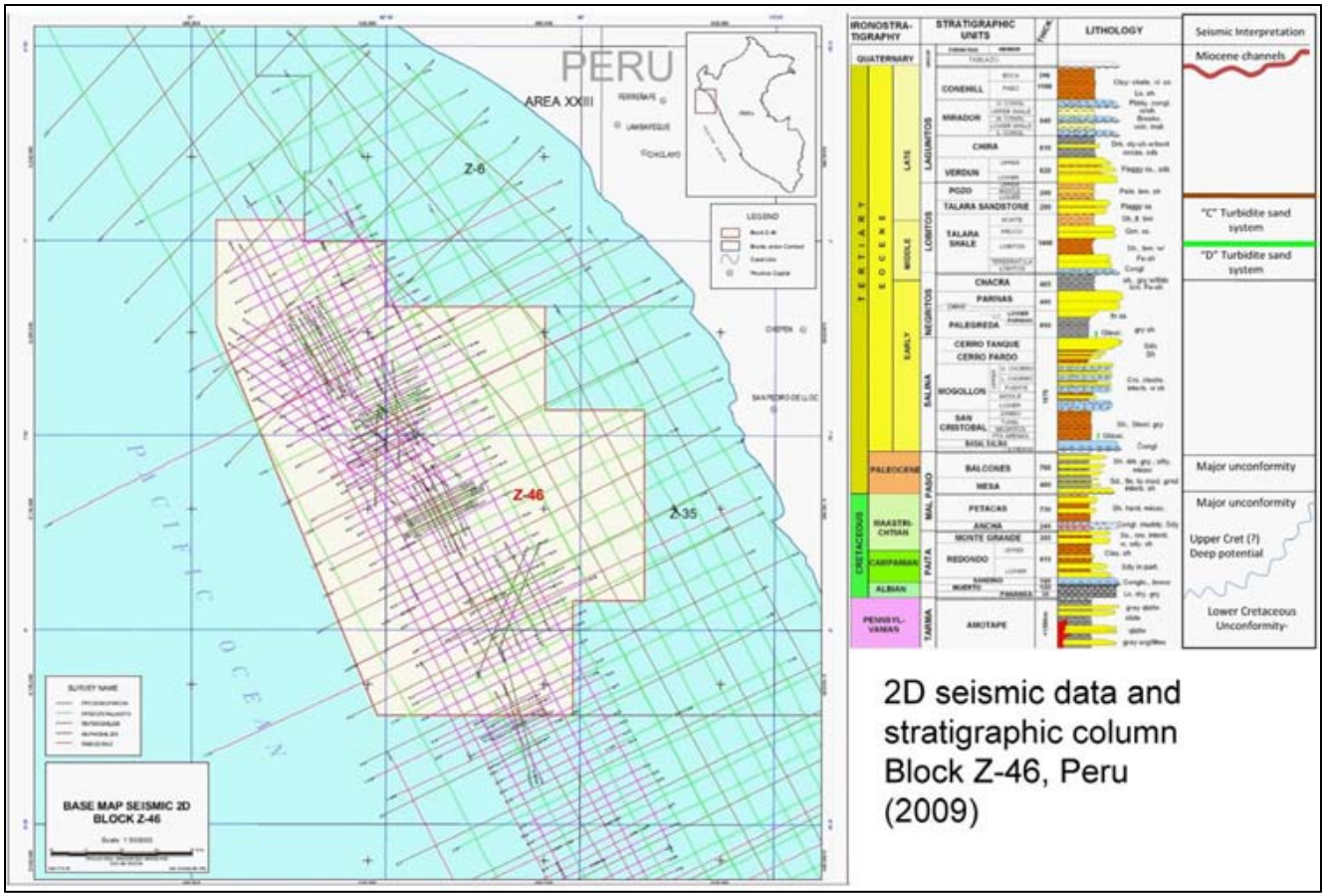

Figure 1. Map of Block Z-46, offshore Peru, Trujillo Basin. 2D seismic lines were acquired during the 1980's and 1990's and reprocessed by SK Energy in 2009.

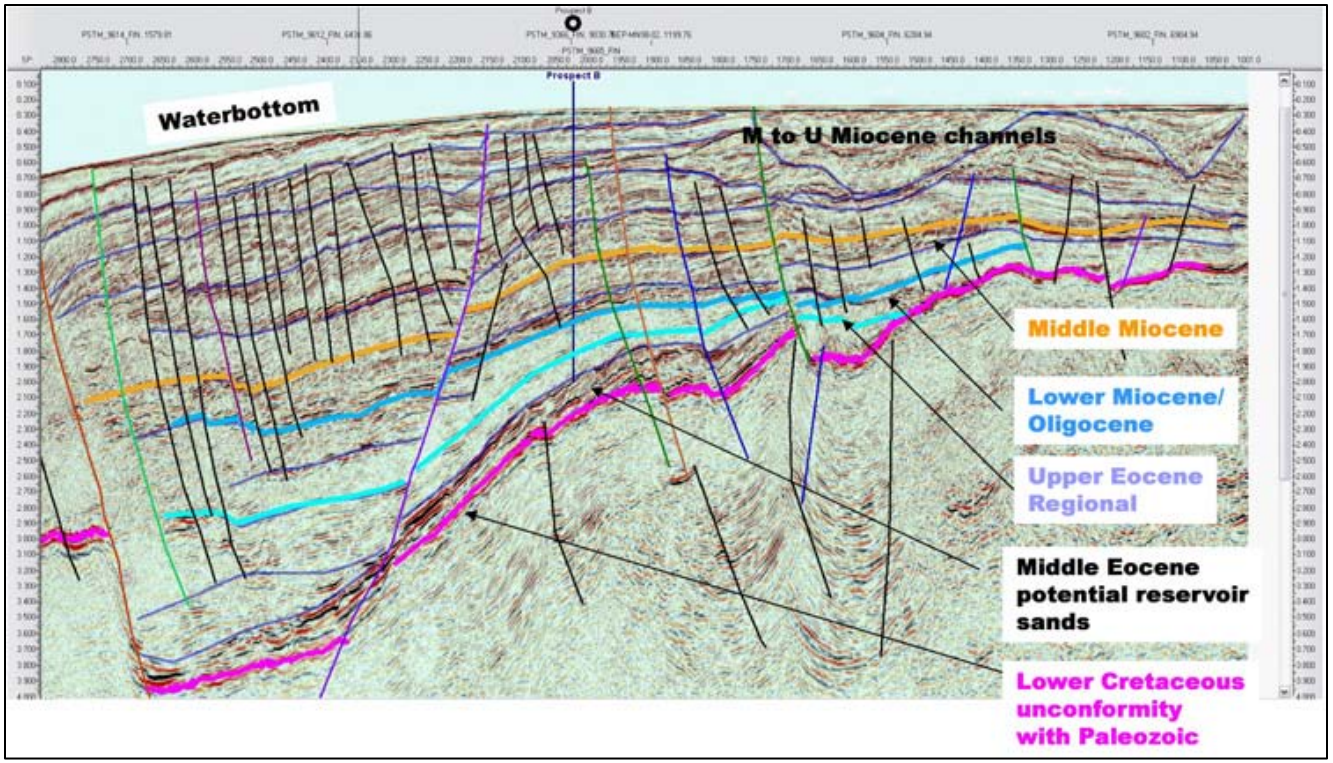

Figure 2. Interpreted sequence stratigraphic ages of reflectors in Block Z-46, Trujillo Basin.

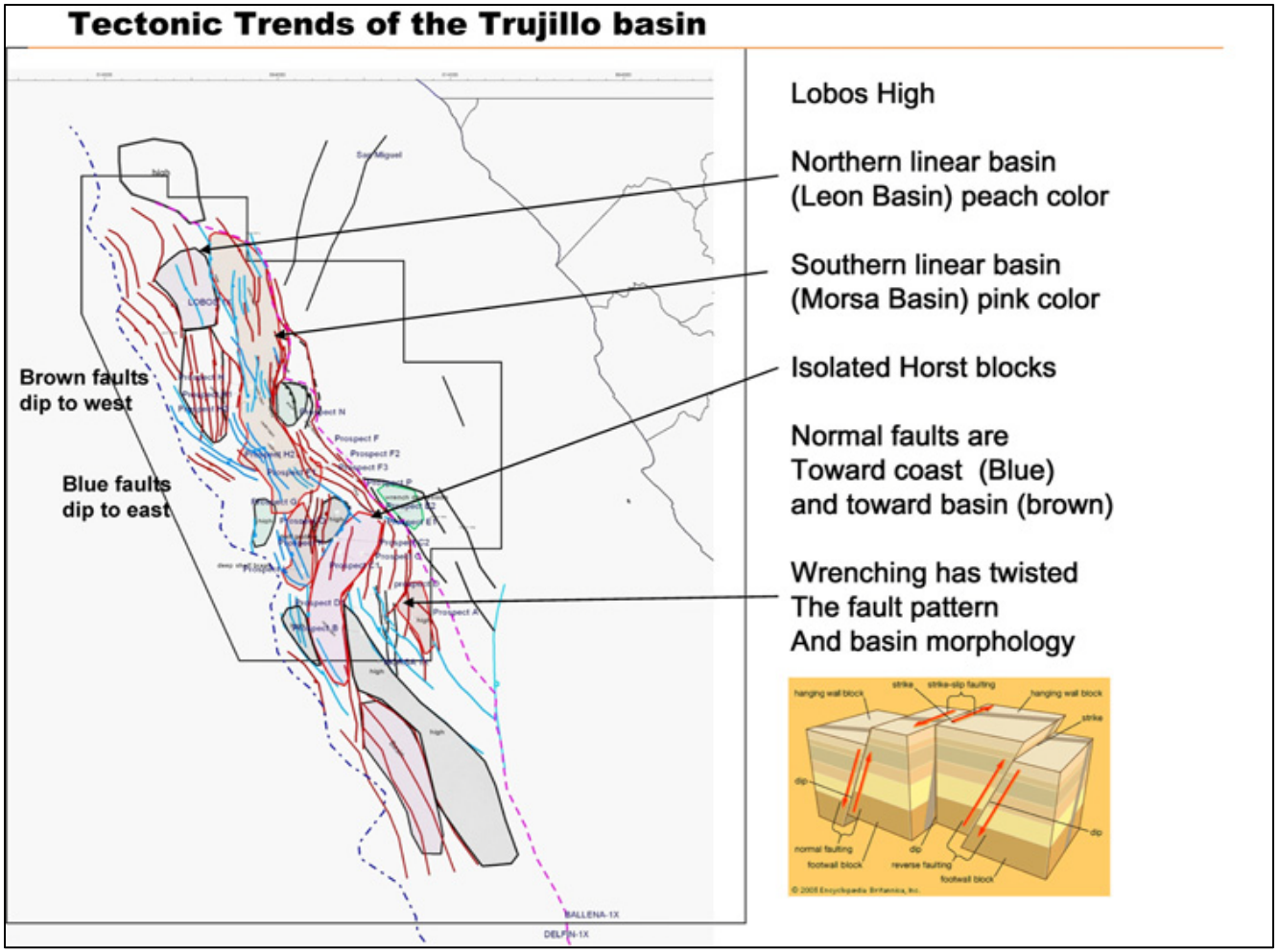

Figure 3. Tectonic map showing the deformed normal faults in the Trujillo Basin, Peru, caused by Tertiary strike-slip deformation that has twisted and rotated the basins.

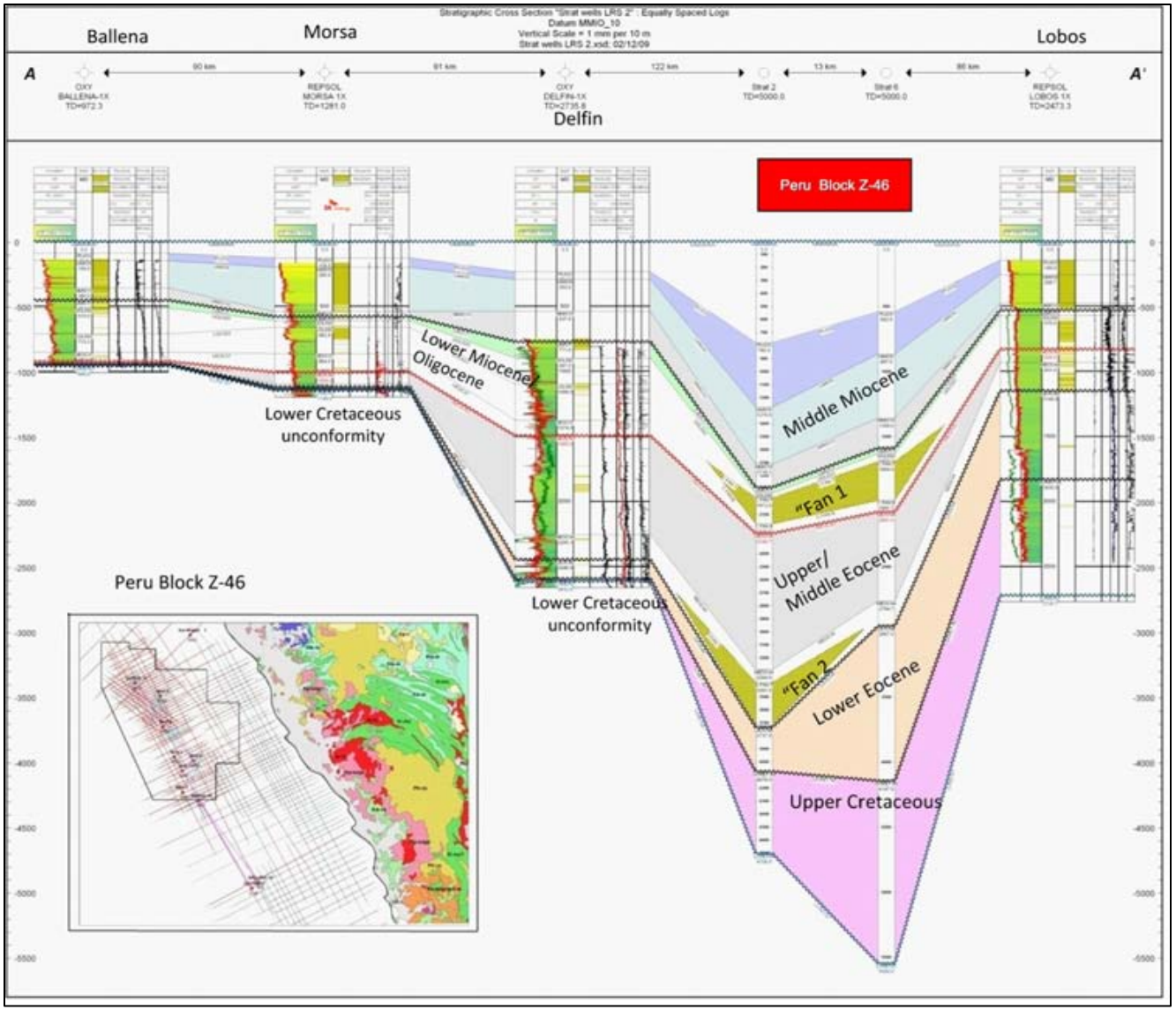

Figure 4. Well cross-section from the south (left) to the north (right) showing the four wells drilled in the Trujillo Basin.

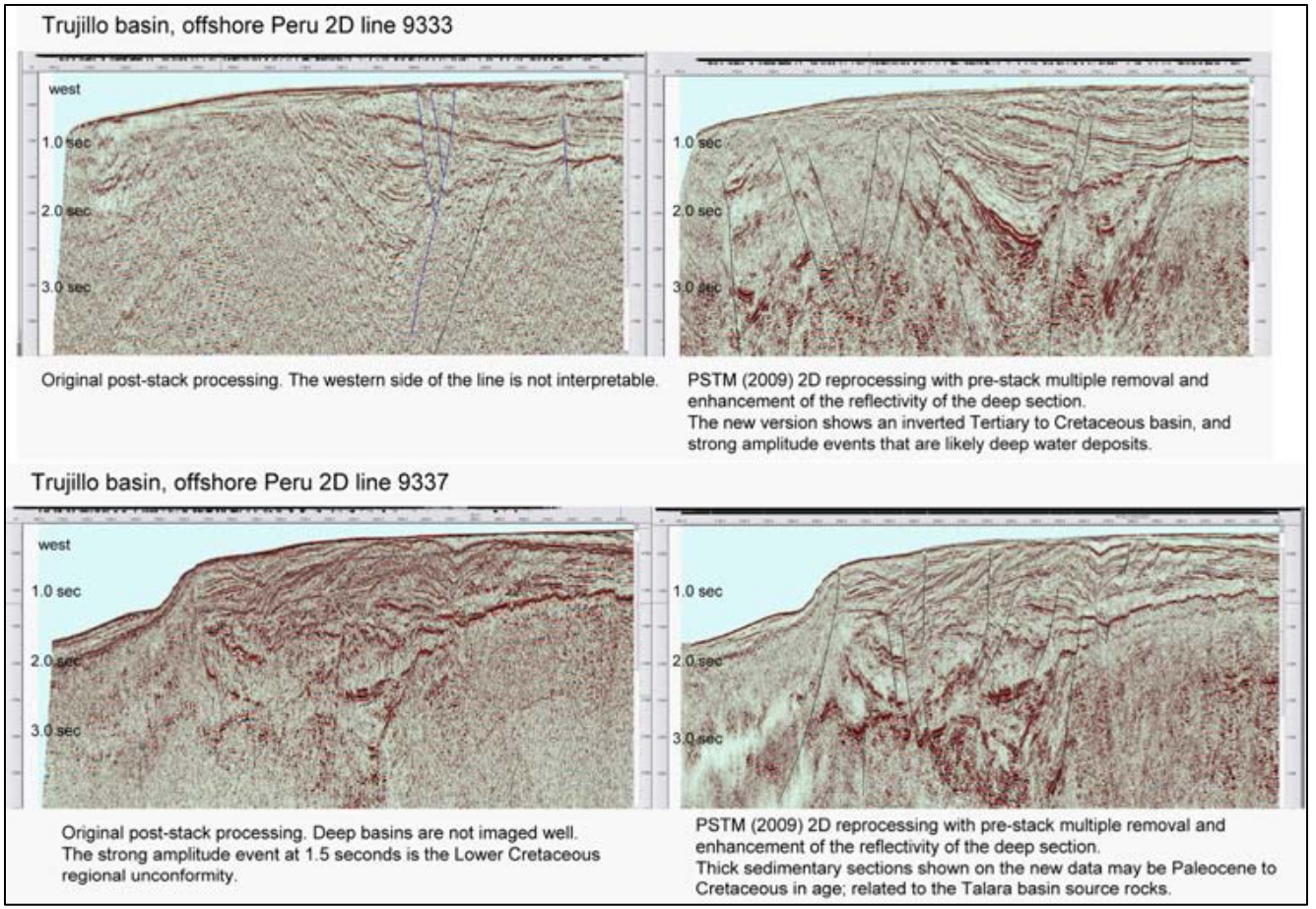

Figure 5. Comparison of original 1990's 2D processing and 2009 PSTM processing.

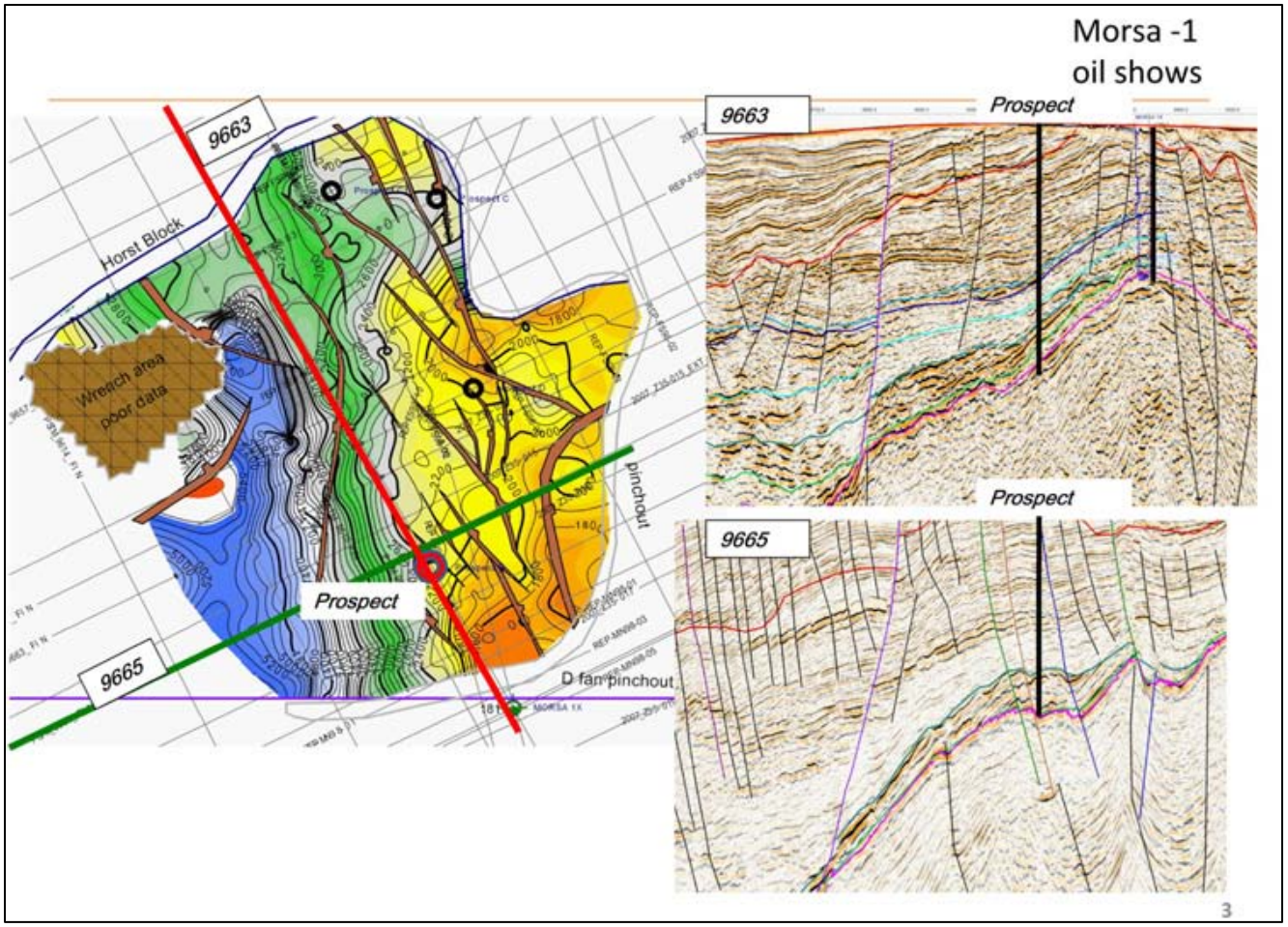

Figure 6. 2D strike and dip lines show a prospective stratigraphic trap with sand-prone Eocene reflectors, downdip from Eocene oil show in the Morsa-1X well.

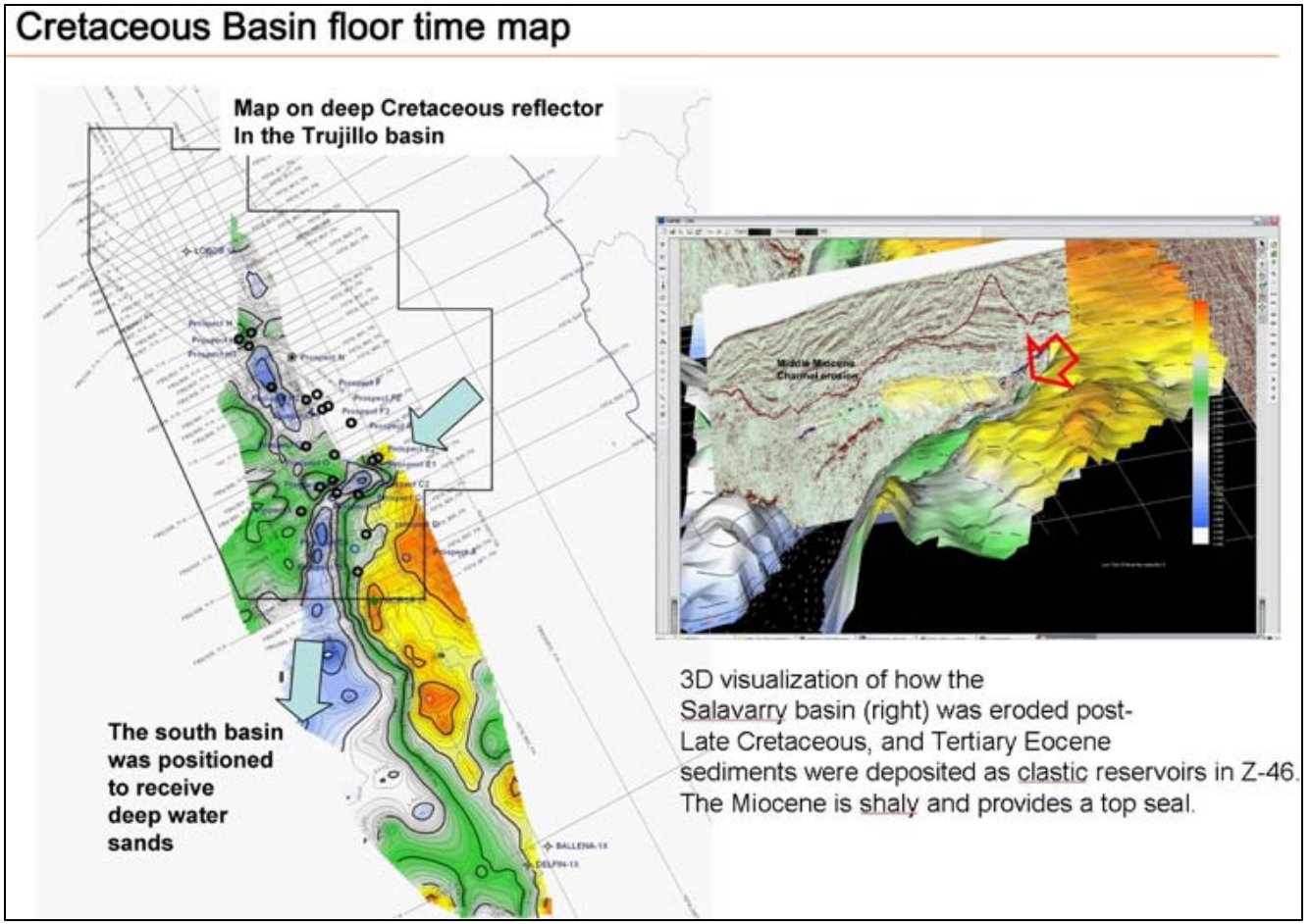

Figure 7. Map of the Lower Cretaceous reflector and a 3D visualization snapshot of the notch point and resulting Eocene submarine fan deposit in Block Z-46.