Delaware Basin PSDM Seismic Data: Why near surface velocity inversion affects image integrity

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Summary

Pre-Stack Depth Migration (PSDM) for Permian Basin seismic data has not been widely adopted. However a few companies began adopting PSDM starting about 4 years ago. PSDM is most commonly associated with complex structural overburden, typical in the Gulf of Mexico Tertiary section where advances in hardware and software have allowed for significant advances in image quality. This paper presents data comparisons in the central Delaware Basin where a deceptively simple structural overburden but a complex lateral velocity profile provides the motivation to use PSDM to improve image quality.

Introduction

Generally, time to depth conversion using a simple velocity function will result in a mis-tie due to lateral velocity changes in the overburden. In processing we would say that is a "depth problem". A typical example is the case of a salt dome where sediments with a velocity of 10,000 feet per second rest unconformably against an intrusive salt with a velocity of 20,000 feet per second. Time migration is not adequate in this case due the limiting assumption of slowly changing lateral velocities. Depth migration, however, improves imaging by iteratively ray tracing through a velocity model until the CDP gathers are flat thus providing the clearest stack possible. The land data shown in this paper exhibit a shallow, high velocity layer of interbedded evaporates and anhydrites overlaying relatively lower velocity sediments. This high velocity, near surface inversion creates the ray path distortions similar to the offshore case of extreme lateral velocity changes.

Delaware Basin and the near surface anhydrates:

The presentation starts with a look at the PSDM data and the ray bending caused by a near surface velocity inversion. (Figure 1). A quick look at a few wells confirms the near surface high velocity inversion. The wells also confirm the velocity and the complexity of not just anhydrite but slower salts within the anhydrite rock and their changing thickness. Both the anhydrites and salts are higher velocity than the underlying shales and sands in the immediate Delaware section. It is this zone immediately below the high velocity layers that is improved from a depth imaging. As we move deeper in the section from the Delaware group into the Bone Spring Group and eventually to the Wolfcamp section, the problem begins to heal itself. Unfortunately, depending on the thickness and complexity of the velocity changes from above, the Bone Spring Group through the top of the Wolfcamp section can be affected. This presentation shows examples of both situations (Figure 2).

Depth imaging helps resolve complex fill zone.

The map in Figure 3 shows the fill zone in the Delaware basin region (V. C Maley, and Roy M Huffington). Where we don't have fill zone, the rock velocity near the surface is generally between 10,000 feet per second to 12,000 feet per section with little weathering. The faster velocity doesn't cause a large static issue or other near surface problems, as we have moderately increasing velocities going into the anhydrite section. However, where the fill zone is present and thickens; a lateral velocity change of approximately 6,000 feet per second transitioning to 12,000 feet per second occurs. Coupling the geologic complexity of the base of the fill with the high velocity salts that come and go in the anhydrite section, results in ray path dispersion and complexity. Time migration breaks down under these conditions, similar to the offshore salt dome example, and forms a degraded image.

Modeling a near surface lateral velocity change with a high velocity inversion at the base of the anhydrite and using pre-stack depth migration can improve the seismic image. This improved seismic image is shown Figures 4 & 5.

Conclusions

The near surface geologic complexity associated with both lateral velocity changes and thick high velocity inversions, create a problem that time migration cannot properly address. The time product is typically more broken up with less continuity than the depth product that unravels the ray paths and forms a far superior image.

References

V. C Maley, and Roy M Huffington, Geological Society of American Bulletin, Cenozoic Fill and Evaporate Solution in the Delaware Basin, Texas and New Mexico: 1953;64;539-546,
doi: 10.1130/0016-7606(1953)64{539:CFAESIJ2.0.CO;2

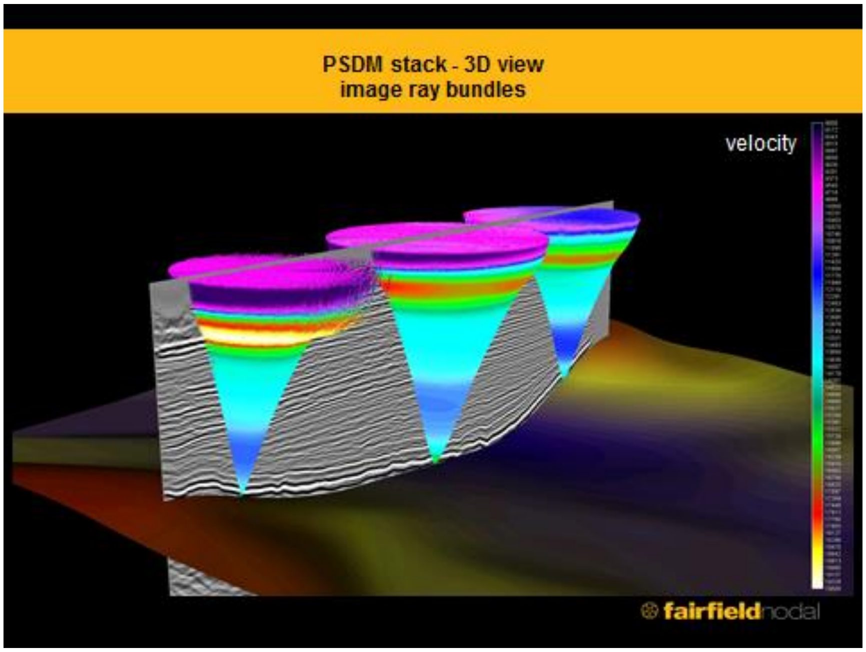

Figure 1. This is an inline with 3 single point reflectors projected from a deeper horizon. The colors from the deep projection are the anisotropic velocity field reflecting back to the surface. The yellow and red layer up shallow show the ray bending associated with the near surface anhydrite layer. The green and light blue colors below anhydrite are the rock packages most affected by these lateral and vertical velocity challenges. The very top shows velocity variations at the surface ranging from as slow as 8,000 feet per second to as high as 12,000 feet per second.

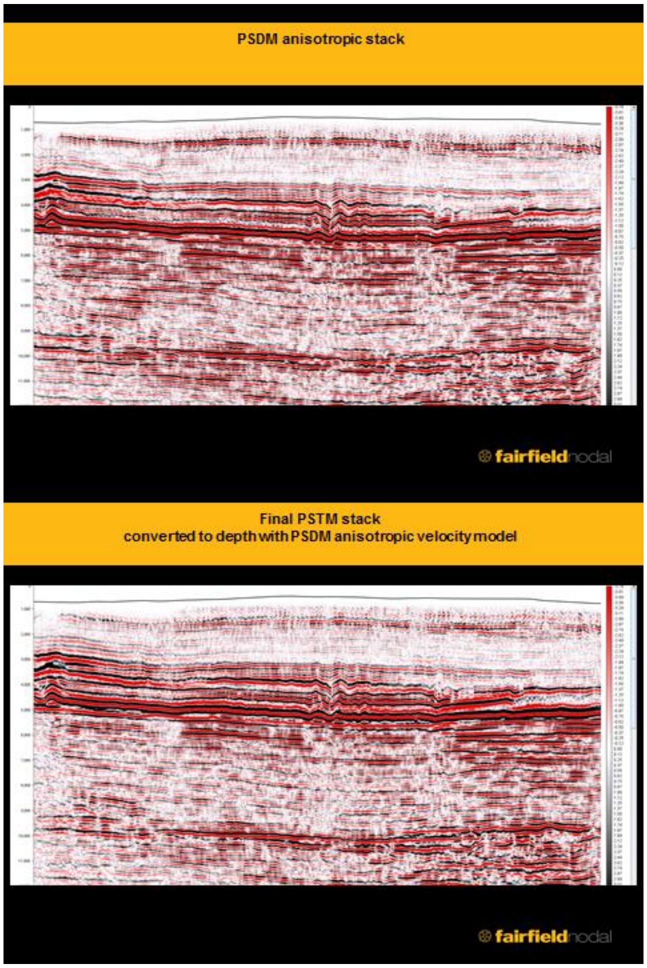

Figure 2. The top section shows the anisotropic depth migrated data and the bottom shows the pre-stack time migrated data stretched using the anisotropic velocity field. The signal is most improved below the high reflectivity section on the left side of the anisotropic depth migrated data.

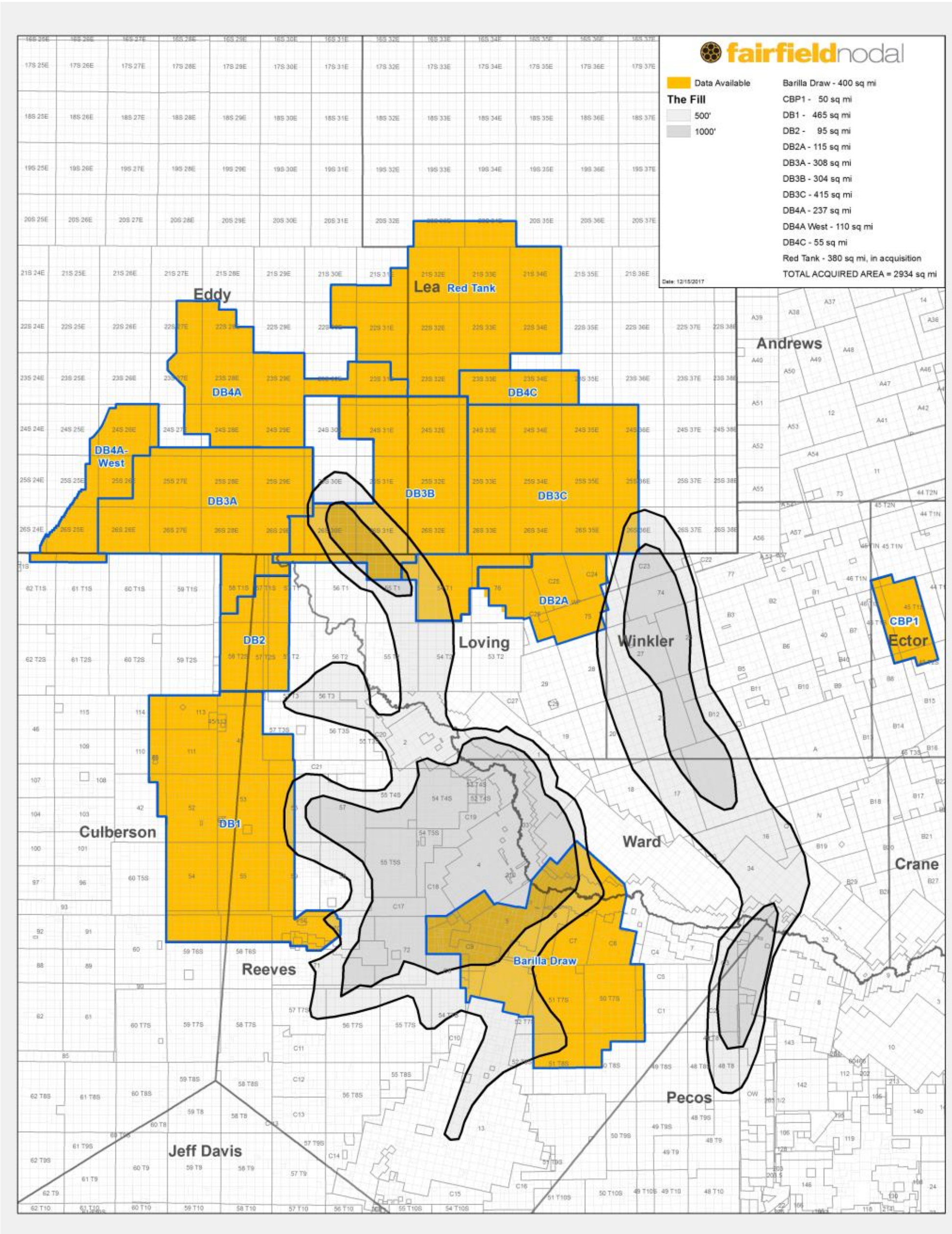

Figure 3. Fill zone contours over the Delaware Basin map for Texas and New Mexico.

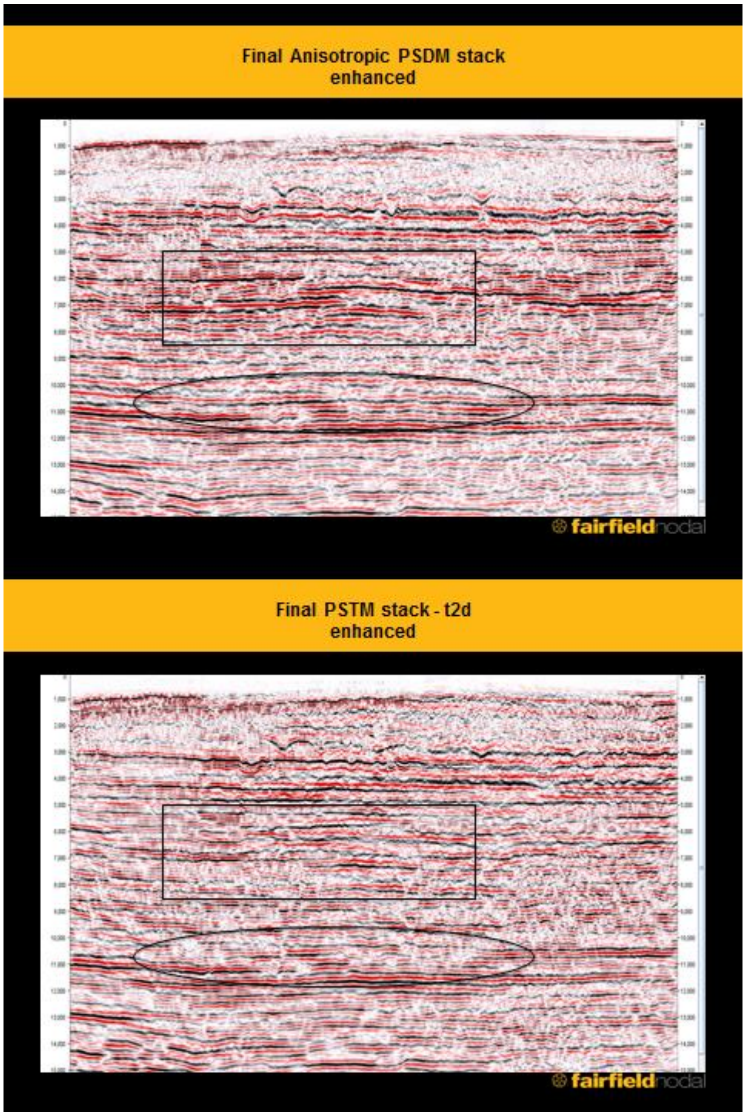

Figure 4 on the top shows a deeper part of the Wolfcamp section in the oval better imaged with depth migration compared to figure 5 on the bottom which is the pre-stack time migrated (PSTM) data stretched to depth. The PSTM data has less continuity then what is thought to be in the geology. The box in both figures shows the bigger continuity changes just below the high velocity shallower anhydrites.