Why 3D Seismic Missed a Giant Field in the Eastern Venezuela Thrust Belt; Postmortem of a Late Discovery

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Introduction

In the Eastern Venezuelan outer foothills, a very large accumulation of hydrocarbon was missed since the late 1980s , despite being covered by several 3D seismic surveys, and being very close to the giant Santa Barbara Field (6.1 MMMbls and 21 TCF). The reason for this accumulation being overlooked was due primarily to not enough communication between geologists and geophysicists that resulted in limited geological input to guide the seismic data processing. Oversights of this type are unfortunately common in our industry. If the geophysical groups and the geologists had been working hand in hand on a regular basis, many problems would have been addressed early and the final seismic volume would have been of much higher quality.

The Lessons Learned:

Over simplified model - normal fault syndrome (Fig.1A and 1B)

Recent structural geology work has interpreted nearly all of the missing geological sections (eg well SBC 90 missing the Naricual superior and Naricual inferior in Fig 1A) as reverse faults with oblique slip or detachment faults. This is a situation that would be expected in a highly thrusted environment such as the foothills. In addition, high quality 2-D seismic lines indicated reverse faulting. Despite this information, geological interpretations showed normal faulting with up to 3000 feet of fault throw. This is an extremely large fault throw for normal faulting and hardly conceivable in a thrust belt.

Multiphase complex tectonic history (Fig.2)

Having a 2D seismic section balanced/restored was thought to be sufficient to support a geological model; the problem was that only one well was used to calibrate/validate the seismic.

Successive tectonic phases have resulted in several thrust/transport directions characterized by high dips of varying azimuths. In a complex environment such as this, 2D cross-section balancing no longer works. Until now, 3D seismic acquisition design has been based on this simplistic regional concept. This has resulted in narrow acquisition patches running in what was originally thought to be the dominant compression direction. This caused spatial aliasing and lack of illumination in the other directions, making seismic processing and interpretation quite challenging. Including additional wells in the validation would have shown the inadequacy of the structural restoration and of the acquisition survey design.

Misuse of computer mapping software (Fig. 1C and 1D)

A major horizontal detachment plane was not recognized. This flat surface was missed by previous geologists because the wells are kilometers apart. A flat surface requires special treatments with computer mapping when the wells with identical depths are isolated from the neighboring wells (eliminating the curvature minimization constraints). Gridding the data without any polygon or fault results in an undulating surface and inappropriate representation of the geological deformation.

Under-use of dipmeter and image logs

Making use of dip data allows to quality control interpretations (Fig.1A and 1B) and the identification of seismic-geology mismatches (Fig.2). The highest dips found in the Santa Barbara field are oriented to the SW, a direction not in line with the dominant regional compression and the seismic acquisition direction. Velocity and anisotropy effects may also have misplaced some events on the seismic image making them inconsistent with the dipmeter data.

Too simplistic layer model for the out-of-sequence shallow thrust

The internal geometry used to represent the Pirital Thrust has a very strong influence on the final image created for the units below; this problem is accentuated by the very high velocities in the thrust that is underlain by a thick shale package with much slower velocities. Because the Pirital Thrust is not a prospective area, geologists are not dedicating any time on these upper units. A better image could only be obtained if the geophysicists were able to convince the geologist(s) to work on getting a more faithful image of the shallow thrust. The large "satellite" field to the northwest of the Santa Barbara field was obvious on recent seismic surveys but it was thought to be a processing artifact (Fig.1C, yellow part affected by side-slip, smearing and pull-up).

Conclusions and Recommendations:

Whereas every company drills expensive wells with seismic interpretation as a pre-requisite, a limited or inappropriate geological input in seismic acquisition and processing can lead to missing significant exploration opportunities.

For future seismic surveys in tectonically complex area, high effort rich-azimuth-offset acquisition (dense large patch) should be considered. This would help deal with multiple transport directions and related high dips. In such complex geological settings with high velocity shallow thrusts, pre-stack depth imaging must be used. Geological interpretation and seismic processing should not be considered as separate processes. Communication should be constant and models should be iteratively refined.

References

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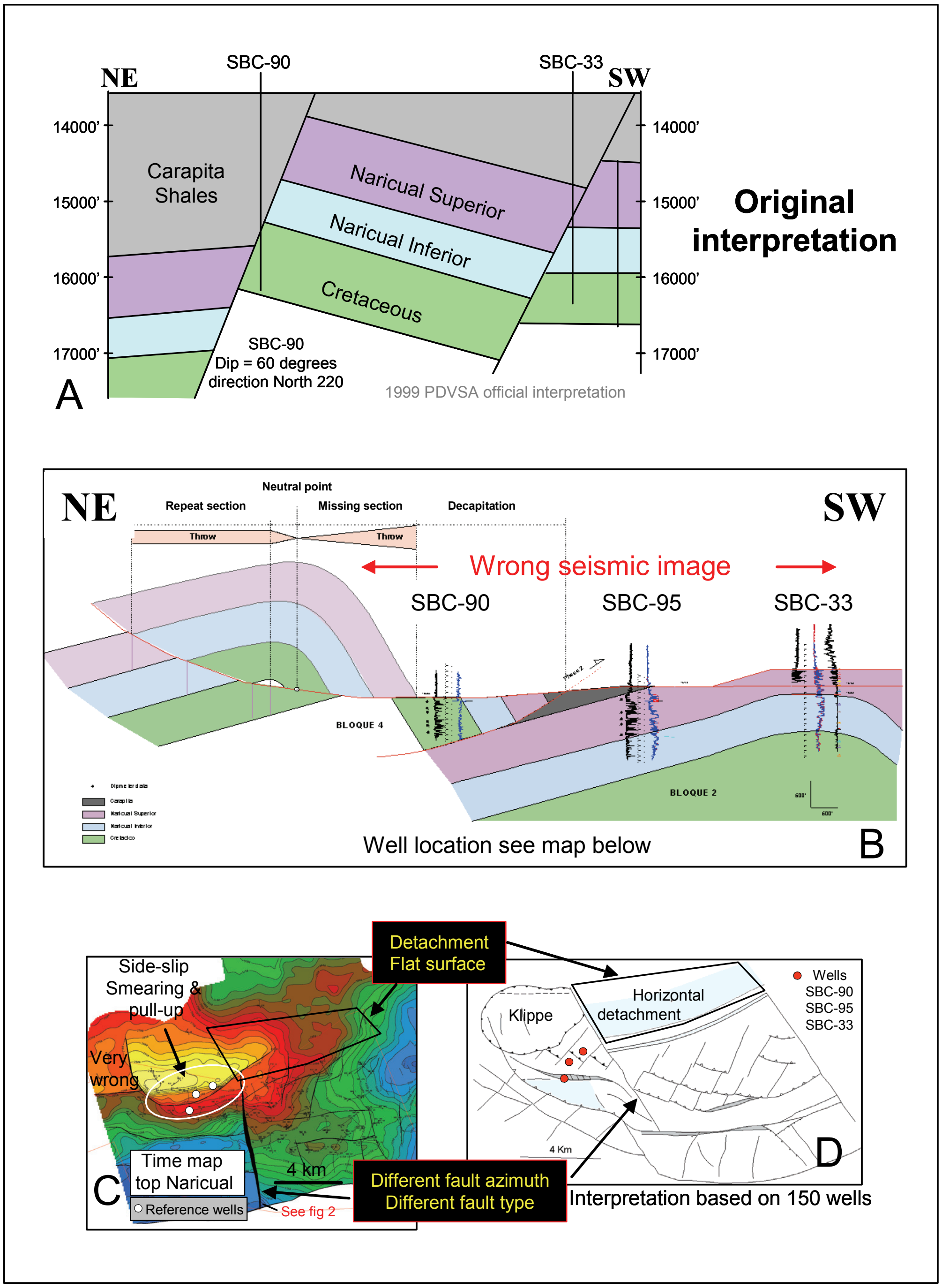
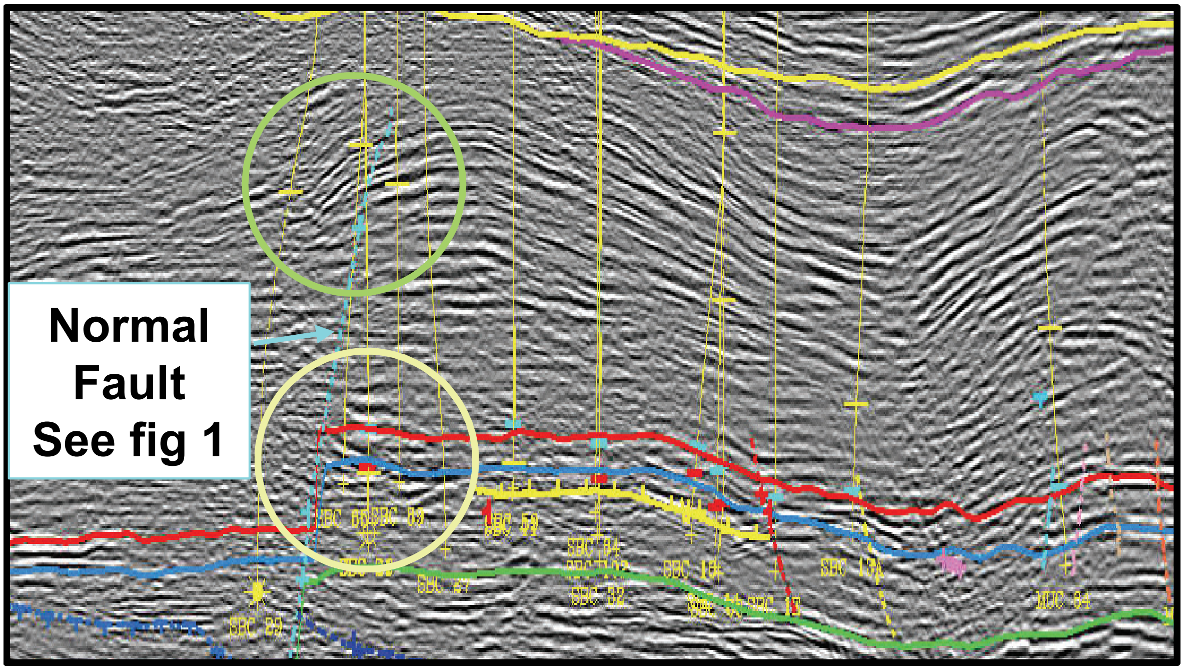
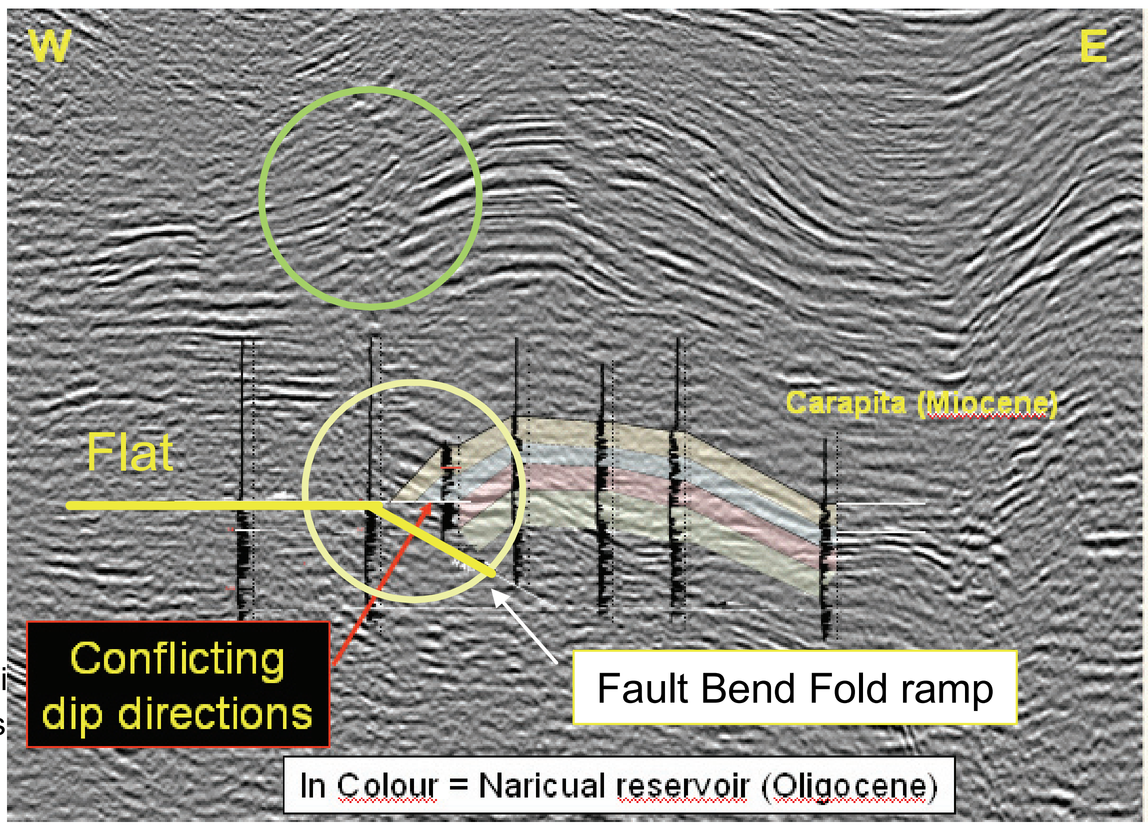


Figure 1: Very different geological interpretations may exist that would require a tighter co-operation between geologists and geophysicists to select the most plausible one



Previous seismic interpretation



Updated seismic interpretation honoring the well data
Note, in the yellow circle, conflicting dip directions between dipmeter and seismic