The Unexpected Should not be Unexplained – New Interpretations via Geoscience and Engineering Anomaly Data Visualization*

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Abstract

A large multidisciplinary study was undertaken following non-acceptable drilling surprises in the Santa Barbara field in wells SBC-109 and SBC-110 (Venezuela). Some of the numerous lessons learned during a period of three years of extensive work will be described with illustrations from the most relevant examples. Despite the existence of several 3-D seismic volumes and more than 100 wells in an area of 190 km^2 (120 mi^2), after drilling more than 13,000 feet of continuous Carapita shale, the reservoir in well SBC-109 was unexpectedly missing the upper 600 feet and was structurally 1,259 feet shallower than SBC-110 whose top came 800 feet below prognosis. These surprises came while the seismic was indicating a flat reservoir top around these wells located 400 meters apart. Whereas other seismic to well mismatches were observed (e.g. against dipmeter data), the focus of the work was on additional data type such as geochemistry and production data. The tools and procedures used will be elaborated in a case study.

Introduction

During an initial quick review, a three-dimensional study of all of the major tops revealed that numerous missing sections originally interpreted as normal faults should be reinterpreted as they lined up horizontally leading to suspect the existence of major detachment faults. The existence of such flat surfaces was satisfactorily confirmed by various production parameters such as “pressures at datum” or by geochemistry with abnormal fluid properties linked to these detachments. Subsequently three of the major detachment surfaces were recognized at the exact same depths in the two giant fields located east of the Santa Barbara field in an area covering more than 50km from West to East.

Subsequently many new and important structural elements were discovered also using production and geochemistry data. Selected examples include:

- 3-D projection plots with orientation dictated by the deformation style allow a quick distinction between normal thickness change due to folding and the existence of repeated folded sections (Figure 1).
- A 3-D analysis of API oil gravity revealing the existence of four thrust sheets; most previous interpretations of the same data had to invoke four to six oil migration phases (Figure 2). At first glance, hydrocarbon seemed to be lighter with depth in each of the wells; the combination of many wells gave a new compelling and simple picture that makes sense with the compressive structural setting of the area.

Discussion and Conclusion

Carbon isotope of isobutane versus depth plots not only helped visualize a major fault not imaged by the seismic and not identified from well data but it also gave an accurate estimate of the fault throw. Repeat Formation tests (RFT) have given outstanding evidences of horizontal detachments and associated deformation bands; they also have confirmed the existence and location of recumbent folds and inverted series that solved many of our unsolved enigmas.

The final geological model was extremely different from any previous ones and more refined; it honors the time sensitive production data with fault patterns that are in line with the structural history of the area. The most dramatic improvement seen has been going from prognosis surprises of the order of 700 feet in infill drilling (SBC-109 and SBC-110) to an incredible zero foot error in the prognosis for SBC-116; an achievement that confirms the importance of recognizing horizontal detachments in a geological model, in thrust belts and in foreland areas hundreds of kilometers away.

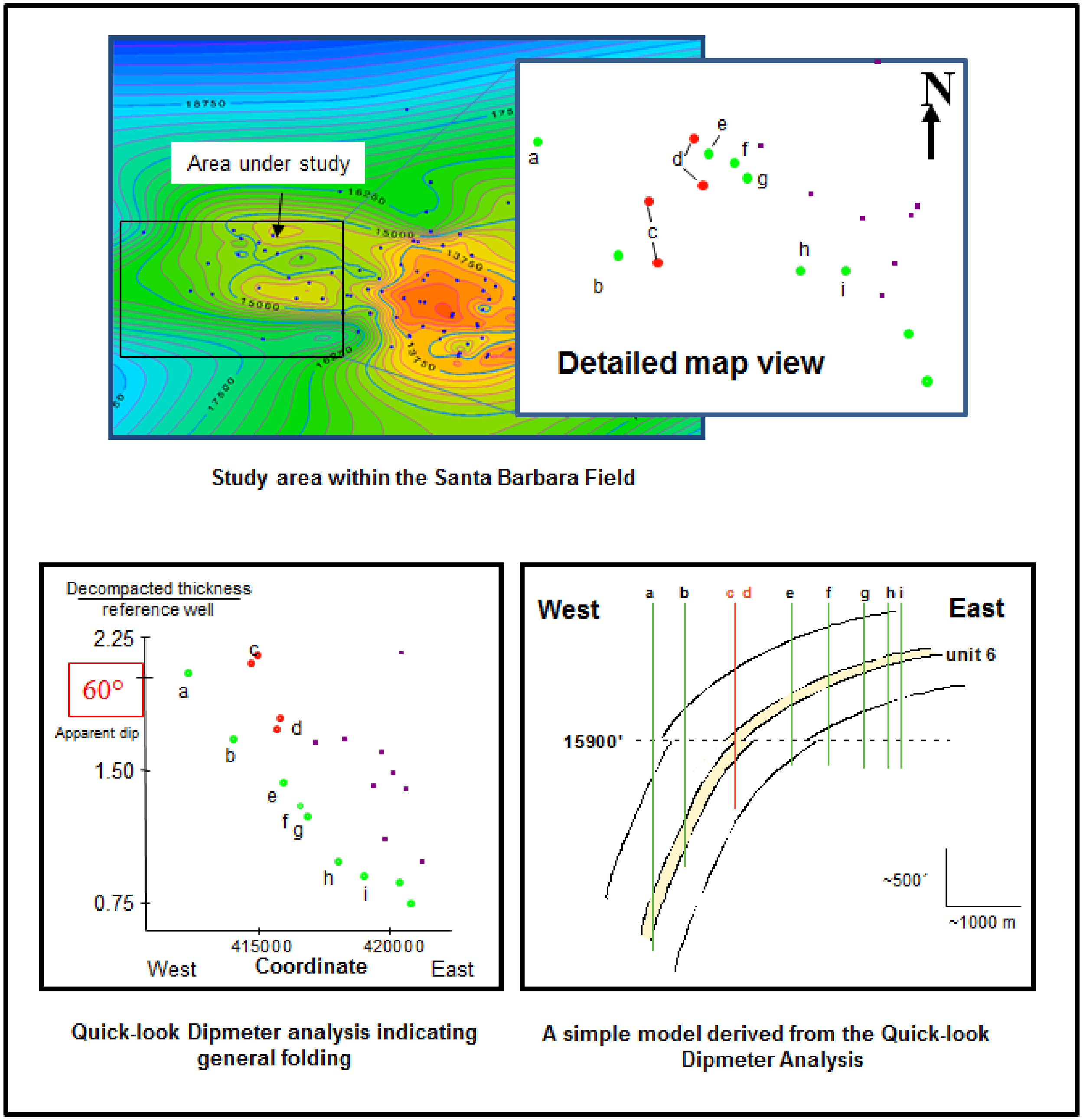

Figure 1. Identification of thickness changes due to folding or due to repeats of folded sections.

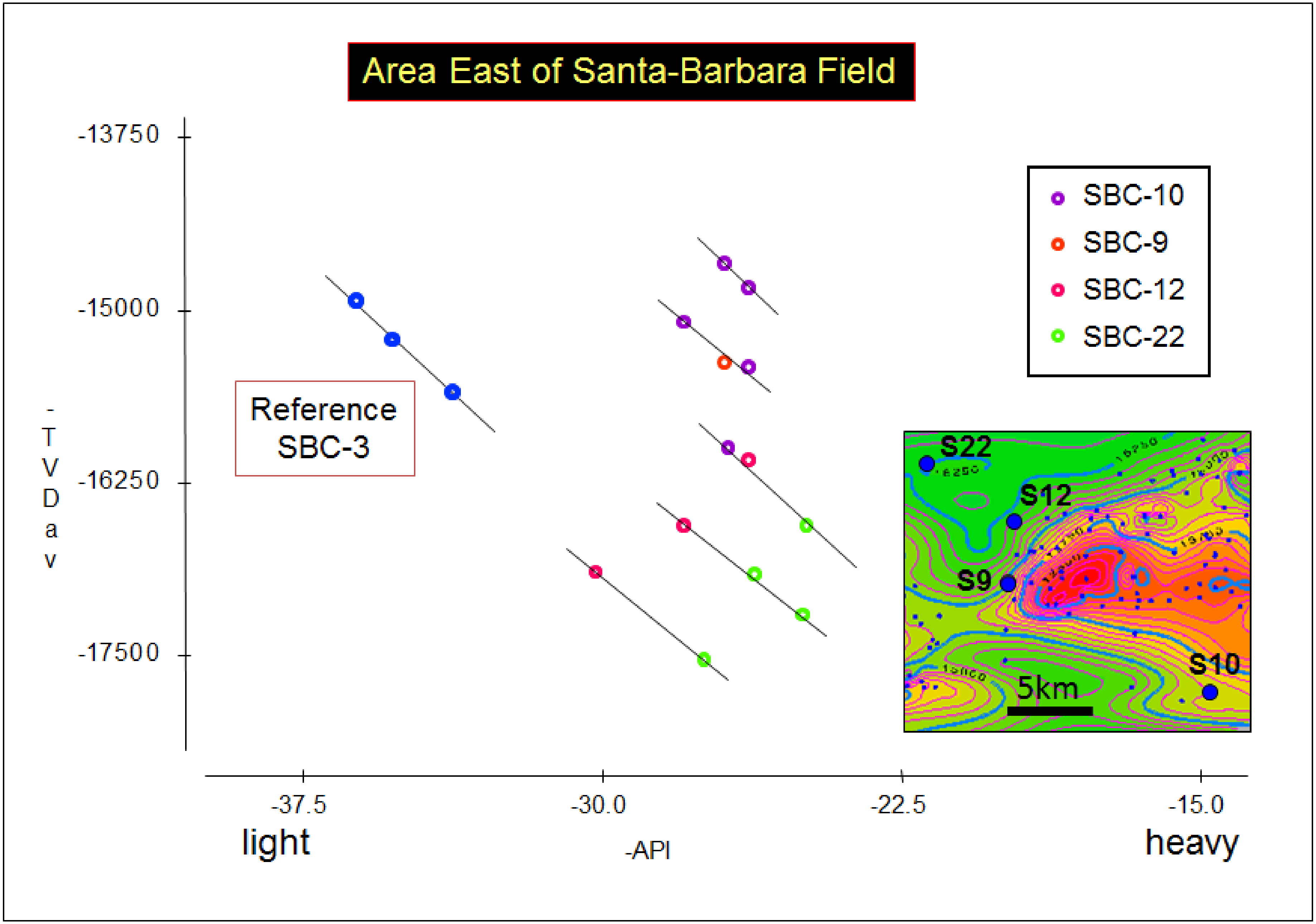

Figure 2. Identification of thrust sheets using simple API versus depth plots.