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Seismic Sedimentology of Miocene Deposits in the Mioceno Norte Area, Lake Maracaibo, Venezuela

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Abstract

This study provides a case history in which the reservoir-level facies interpretation in a densely drilled, but spatially restricted, area containing 240 wells is extended to a bigger, 3-D-survey area by means of seismic sedimentology. In turn, seismic facies images verify and improve upon the existing facies interpretation by adding control between and beyond wells.

INTRODUCTION

Seismic sedimentology is the use of seismic data to study sedimentary rocks and the processes by which they form. It differs from seismic stratigraphy and sequence stratigraphy in that it uses principally horizontal, as opposed to vertical, resolution of seismic data to image high-resolution depositional patterns that link directly to modern and ancient depositional models. A display of seismic attributes on geologic time surfaces is a basic tool of seismic sedimentology. In the early days of 3-D seismic technology, time slices and horizon slices provided occasionally sharp, satellite-picturelike depositional-facies images (for example, Brown, 1991). However, strict application conditions (the slice must be chosen at or parallel to a geologic time-equivalent seismic event) prevent 3-D seismic from being used in more complicated depositional sequences. Zeng and others (1995, 1998a, b) and Posamentier and others (1996) showed that a stratal slicing of 3-D seismic data overcomes some of the shortcomings of horizon slicing by proportionally slicing between geologic time-equivalent seismic reference events, which makes the seismic mapping on depositional surfaces easier.

Miocene deposits of the Mioceno Norte Area, Lake Maracaibo, Venezuela, provide an excellent example for illustrating this seismic sedimentological approach. The Mioceno Norte Area occupies an anticline (Figure 1) bounded by thrust faults that extend from the Eocene and deeper formations to the top of the Miocene. However, the relatively simple structure doesn't make sequence stratigraphic analysis easier. Beyond the narrow structure where most of the production occurs, the area is mostly undrilled. Except for the few sequence boundary reflections, internal seismic events are mostly discontinuous and difficult, if not impossible, to trace. A vague discontinuous, variable-amplitude facies may be the best definition of seismic facies for the 600-ms formations, which provide very low resolution (but spatially controlled) information about depositional systems and history.

The high-resolution (reservoir level) stratigraphic framework was done by Ambrose and others (1998) (Figure 2) before the 3-D seismic data had been collected. After correlating low-resistivity shale markers in approximately 240 wells in the field, they divided the 2,500-ft Miocene deposits, from the Santa Barbara to Lower Bachaquero intervals, into 30 genetic stratigraphic units, each 50 to 150 ft thick. Further mapping and interpretation showed that the origin of the clastic genetic units are shoreface, deltaic, and fluvial. An important conclusion of the study is that a major source area of those Miocene deposits was from the west and northwest, which controls the trend and, therefore, distribution and potential of the oil reservoir.

This study started with the correlation of the four sequence boundaries (SB10, LL90, LaS90, and BACHS10, Figure 1) that represent the major geologic time surfaces of the Miocene in the 3-D seismic data. A stratal slicing, performed by running a user-code program, created a stratal slice volume of the Miocene deposits. Those stratal slices were then tied to the geologic framework (Figure 1) in order to (1) compare the depositional patterns and source directions with those on well-derived maps, (2) extend the high-resolution facies study from the densely drilled field to the bigger, 3-D survey area, and (3) reveal Miocene depositional history in the area.

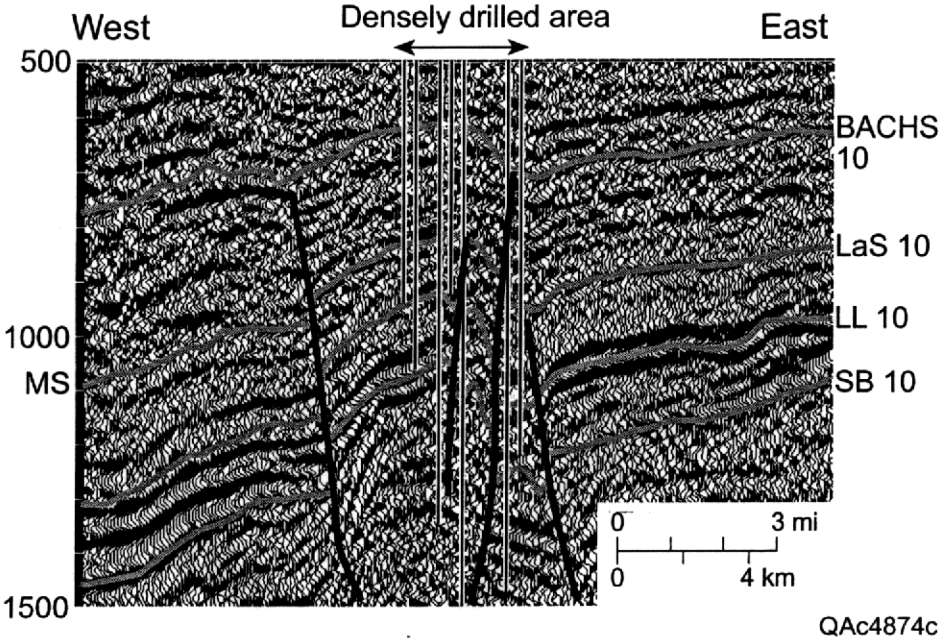

Figure 1. A typical seismic line in the Mioceno Norte Area.

FLUVIAL-DELTAIC DEPOSITS

Most genetic units in the upper portion of the Miocene succession (Figure 1) are fluvial-deltaic in origin. A typical example, the BACHI 40-50 unit, is 60 to 80 ft thick in the field area (Figures 1 and 3). Observed in core, bounding marker beds are silty shales having roots and mud cracks. Some cores consist mostly of siltstones, soil zones, and thin (5- to 10-ft), upward-fining, fine- and medium-grained sandstones interpreted to be crevasse-channel deposits in a channel-margin setting. Main channel-fill and point-bar sandstones are inferred mostly from blocky or upward-fining log responses that are individually more than 20 ft thick. Interaxial areas of less than 20 ft net sandstones have muddy-serrate and spiky log responses. Judging from interwell thickness mapping, these channels have mainly anastomosing, northwest-southeast trends.

Stratal slices of the BACHI 40-50 unit illustrate at least three distinctive fluvial-deltaic systems that were formed in slightly different geologic times. The most significant one (Figure 4) reveals many linear, channellike amplitude patterns. These channels run mostly from northwest to southeast, many of which can be traced across the structure bounded by faults. Some of the channels to the northwest of the structure have anastomosing patterns; those to the southeast of the structure are straighter and more bifurcating, grading southeastward into a deltaic system. Amplitudes between channels are commonly fan shaped to random, representing levee, crevasse-splay, and floodplain deposits.

In this example, the resemblance between the results from the two different approaches lies in their (1) similar depositional source (northwest), (2) similar channel size (100 to 500 m), and (3) similar channel type (anastomosing). An advantage of seismic sedimentology is that it does not rely heavily on the availability of well data and is indeed a powerful supplemental tool in delineating sand-body geometries in sparsely drilled areas. However, one should be aware that the pattern recognition on stratal slices is not necessarily a direct recovery of reservoir properties, which in general requires further evaluation (for example, attribute analysis, generalized inversion). Also, a stratal slice may represent a geologic time unit different from (and in this case smaller than) that of a genetic stratigraphic unit. As a result, a stratal slice is rarely a total duplication of a genetic unit-based facies map.

SHOREFACE SEDIMENTS

Shoreface reservoirs in the Mioceno Norte area are limited to the La Rosa Formation and the basal genetic stratigraphic unit in the Lower Lagunillas Formation (Figure 1). In contrast to fluvial and deltaic systems in the field, these shoreface sandstones contain thick (>40-ft), continuous sandstones. they exhibit a generally southwest-northeast trend. Stratal slices in these genetic units illustrate similar southwest-northeast trending of the sandstones and also a shoreline retreat toward the northwest with geologic time (not shown).

DEPOSITIONAL HISTORY

A stratal slice movie, made from the bottom to the top of the Miocene seismic sequence (not shown), further exhibits the area's depositional history. Guided by facies interpretation at well locations, stratal slices are capable of offering detailed information about the cyclicity of deposition, facies migration, and reservoir distribution, all as a function of space and geologic time.

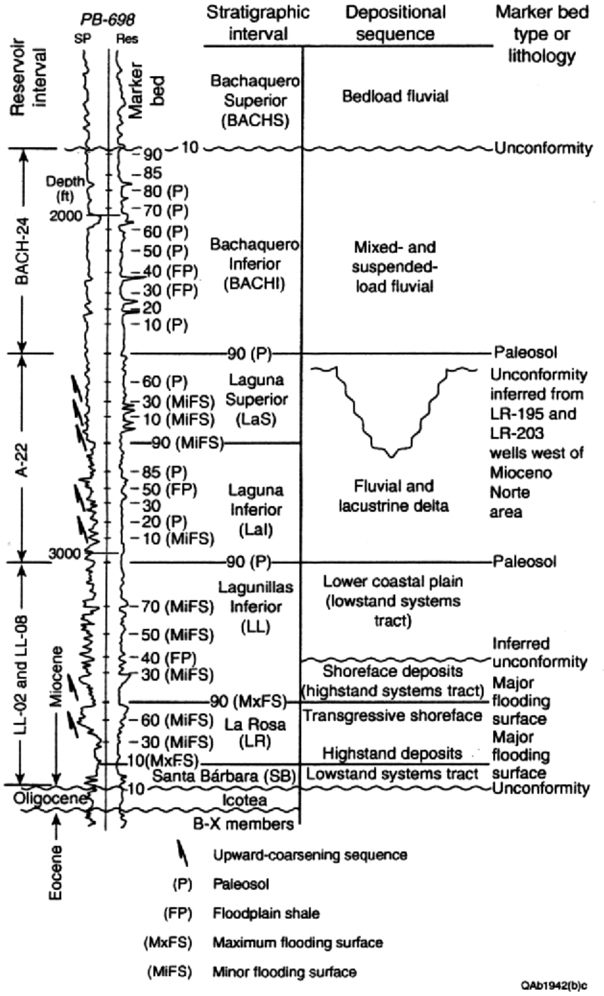

Figure 2. Type log showing genetic stratigraphic units and major sequences in this study.

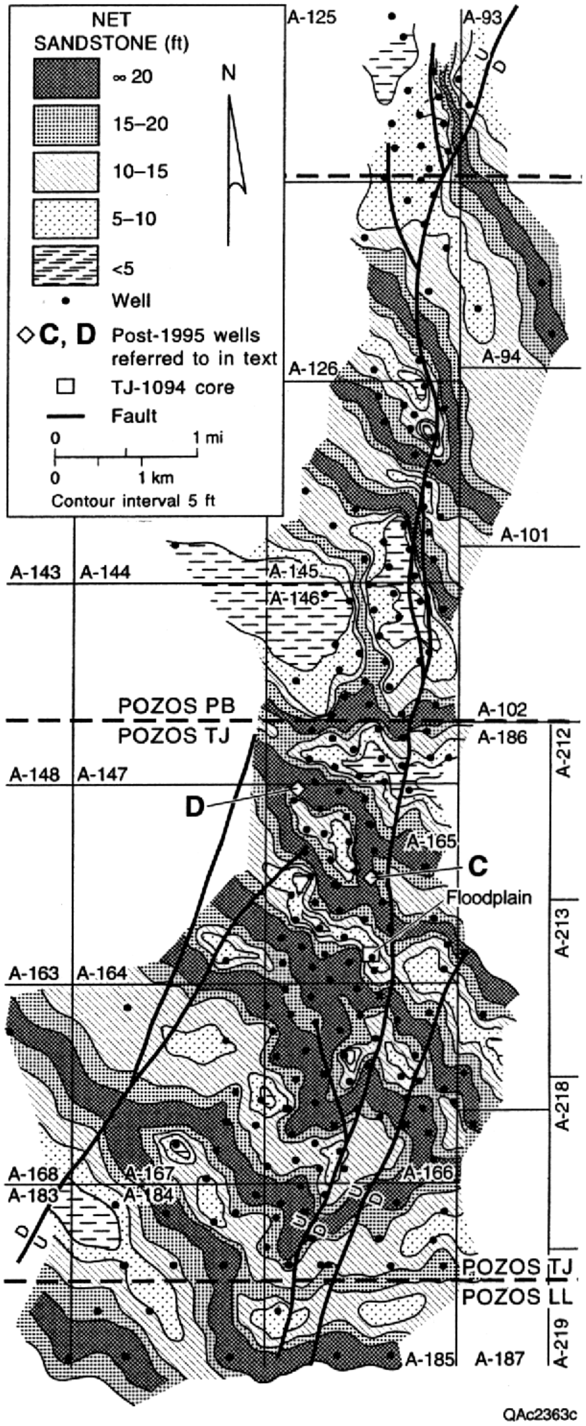

Figure 3. Fluvial channels recognized in the net-sandstone map of the BACHI 40-50 genetic stratigraphic unit.

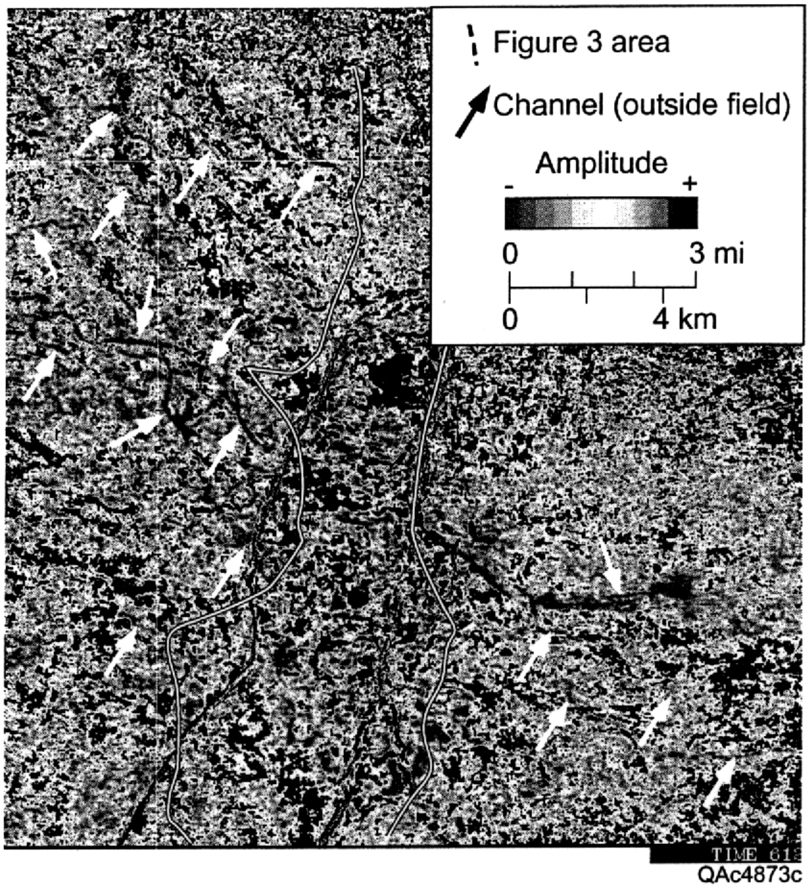

Figure 4. Fluvial-deltaic system imaged in one of the stratal slices within the BACHI 40-50 genetic stratigraphic unit.

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