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ABSTRACT

PROXIMITY AND LATERALITY INDEXES: A NEW TOOL FOR THE ANALYSIS OF ANCIENT HYPERPYCNAL DEPOSITS IN THE SUBSURFACE

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Introduction

Recent advances in the understanding of a new category of depositional system, termed hyperpycnal system, offer new perspectives to improve the understanding of the distribution of sandstone packages. A hyperpycnal system is the subaqueous extension of the fluvial system (Zavala et al., 2006a), and develops as a consequence of a relatively high density discharge during a flood. Because of their long duration and high sediment concentration, these flows have the capacity of travel 100's of kilometers basinward also in low gradient systems, and to built-up very thick successions especially in topography controlled depocenters. Hyperpycnal systems often inherit some characteristics often erroneously considered as typical of fluvial deposition, like bedload, channelizing and meandering. The main goal of this contribution is to introduce the methodology used for facies analysis on hyperpycnal deposits applied to a subsurface study of the Oligocene-early Miocene Naricual Formation in the Eastern Venezuela Basin.

Facies analysis: a genetic approach

The Naricual Formation is one o the main oil-bearing unit of the Maturin foreland in the Eastern Venezuelan Basin. It is composed of up to 2,000 m-thick of clastic deposits. A preliminary analysis of the main facies types present in this unit show a dominance of composite beds (Zavala et al. 2007) related to long lived and quasi-steady sediment gravity flows. The association of these facies with lofting rhythmites (Zavala et al. 2006b), the abundance of plant remnants and the presence of marine microfossils suggest an origin related to a direct fluvial discharge in a shallow marine environment. Consequently, a hyperpycnal origin was proposed for these deposits. With the scope of facies mapping and reservoir prediction, sedimentary facies were analyzed and classified according to their genetic significance. More than 5,000 m of cores pertaining to 40 wells of the Bosque-Travi field were analyzed. The basic classification schema used in this study is shown in Fig. 1 (Zavala et al. 2006c), and is based in the distinction of three main facies categories related to bedload (Facies B), suspended load (Facies S) and lofting (Facies L).

Facies B comprises the coarsest materials present in the tract transported by drag and shear forces provided by the overpassing turbulent hyperpycnal flow. Three main categories are recognized, termed B1 (massive fine grained conglomerates), B2 (pebbly sandstones with low angle asymptotic cross-stratification) and B3 (pebbly sandstones with diffuse planar lamination). **Facies S** are almost fine grained, and relate to the gravitational collapse of suspended load transported in turbulence in the main body of the hyperpycnal flow.

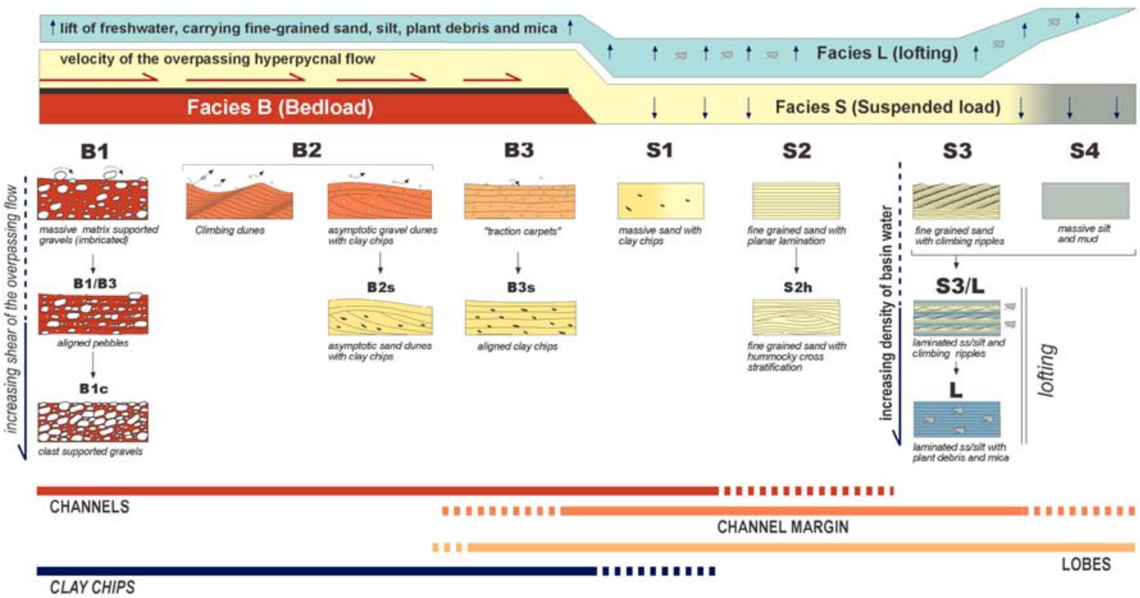

Figure 1.

The genetic classification of hyperpycnal facies used in this work. Facies B relate to bedload while facies S are related to the gravitational collapse of the coarsest fraction of the suspended load, as the flow wanes. Lofting facies (L) are related to the gravitational flow onset provoked by the uplift of the freshwater contained in the flow.

Four facies types are recognized within this category, denominated S1 (massive sandstones), S2 (laminated sandstones), S3 (sandstones with climbing ripples) and S4 (massive siltstones and mudstones). **Facies L** (lofting) relates to the buoyancy reversal provoked by the lift-up of a less dense fluid (in the case freshwater) on marine environments (Zavala et al. 2006b). Finest suspended materials are also lifted from the substrate, and settle down forming silt/sand couplets of great lateral extension. Facies analysis based on a genetic classification provides new perspectives to the paleoenvironmental understanding and the prediction of reservoir quality. The genetic-oriented analysis applied to the study of hyperpycnal systems allowed the facies mapping and the recognition of bypass, depositional and lateral areas in the subsurface. With the scope of better managing the facies dataset, two main indexes were considered in this study, termed as proximity (Pt) and laterality (Lt) indexes. These indexes were calculated individually for each studied well.

The proximity index (Pt)

The Pt index is a dimensionless number that measures how proximal the well is located respect to the system considered as a whole. It is based in the relative dominance of bedload facies in proximal positions and the basinward increasing of suspended load facies as the long-lived hyperpycnal flow progressively wanes with the subsequent collapse of suspended materials. In its simple form, the proximity index can be written as follow.

$$Pt = 100 \frac{B}{B+S}$$

Where Pt is the proximity index, B is the total thickness of bedload facies and S is the total thickness of suspended load facies in the analyzed core. Note that only the hyperpycnal facies are considered.

The Pt index varies between 0 and 100. The greater the Pt index is, the more proximal the considered location will be within the hyperpycnal system. In fact, Pt indexes between 100 and 50 characterize proximal system areas, while Pt indexes comprised between 50 and 0 suggest medium system areas. When the Pt reaches 0, it marks the channel-lobe transition and the beginning of the distal system area. Additionally, the decay rate of the proximity index can be used as a proxy to estimate the dimensions of the system under study.

The laterality index (Lt)

Because of the gravity nature of the hyperpycnal flow, coarse grained facies are very sensitive to any subaqueous topography. Facies B and S tend to develop infilling the lowermost positions of the submarine landscape. On the contrary, lofting facies mostly characterize relatively elevated areas located laterally respect to the main axis of the hyperpycnal flows. Consequently, the Lt index is a dimensionless number that will measure the relative location of the analyzed well respect to the main depocentres. The Lt index is useful to delineate the location of synsedimentary-growing tectonic structures in the subsurface. The laterally index can be obtained as follows:

$$Lt = 100 \frac{L}{L+B+S}$$

Where Lt is the laterality index, L is the total thickness of lofting facies, B is the total thickness of bedload facies and S is the total thickness of suspended load facies in the analyzed core. Note that only the hyperpycnal facies are considered.

In the main depocenters affected by coarse grained hyperpycnal sedimentation, the laterality index tend to be low, typically less than 15, while lateral uplifted areas has laterality indexes that exceeds 35.

First results

The analysis performed on the Naricual Formation revealed the gravitative nature of most clastic facies. Dominant facies are massive medium to fine grained sandstones (S1) and coarse grained to pebbly sandstones with diffuse lamination and aligned clasts (B3). Proximity indexes vary from 73 to 30, and suggest a proximal to medium position along the entire field. Preliminary analysis of the proximity decay rate suggests a system bigger than previously considered. Vertical changes in the laterality indexes indicate several synsedimentary growing structures that deeply controlled the location of main sandstone bodies.

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