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Sedimentological Indexes: A New Tool for Regional Studies of Hyperpycnal Systems

Carlos Zavala[1,2], Jair Carvajal[2], Jose Marcano[2], and Manuel Delgado[2]

1) IADO, CONICET. Camino la Carrindanga Km 7.6, Bahía Blanca, 8000, Argentina
(2) PDVSA Exploración Oriente. Puerto La Cruz, Venezuela

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 (Fig. 1). 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 settings, and to built-up very thick successions especially in topography controlled depocenters. Hyperpycnal systems often inherit some characteristics frequently erroneously considered as typical of fluvial deposition, like bedload, channelizing and meandering.

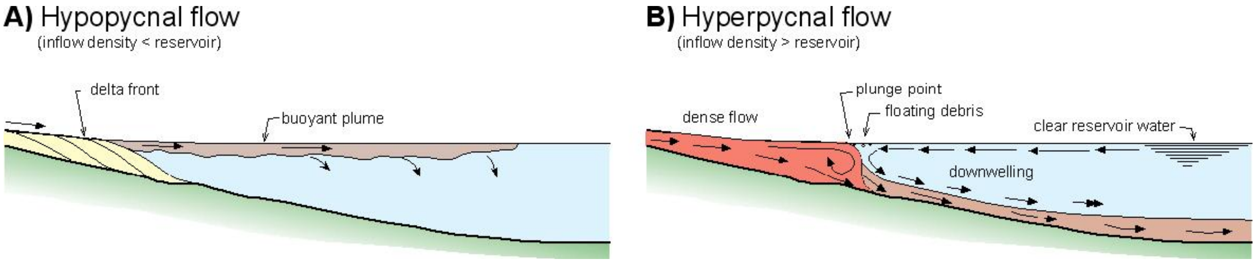

Figure 1. Comparison between hypopycnal (A, inflow density < reservoir) and hyperpycnal (B, inflow density > reservoir) flows (original concept by Bates, 1953). Note that in the case of the hyperpycnal flow the fluvial discharge sinks below the water body continuing its travel basinward as a quasi-steady underflow. Figure 1B was redrawn from a pioneer work after Knapp (1943).

In contrary to conventional models for turbidity sedimentation (Mutti et al. 1999), in long-lived hyperpycnal flows coarse grained materials are not transported at the flow head, but are dragged at the base of the turbulent flow as bedload (Fig. 2) due to shear forces provided by the overpassing long-lived turbulent flow (Plink-Björklund & Steel, 2004; Zavala et al. 2006b).

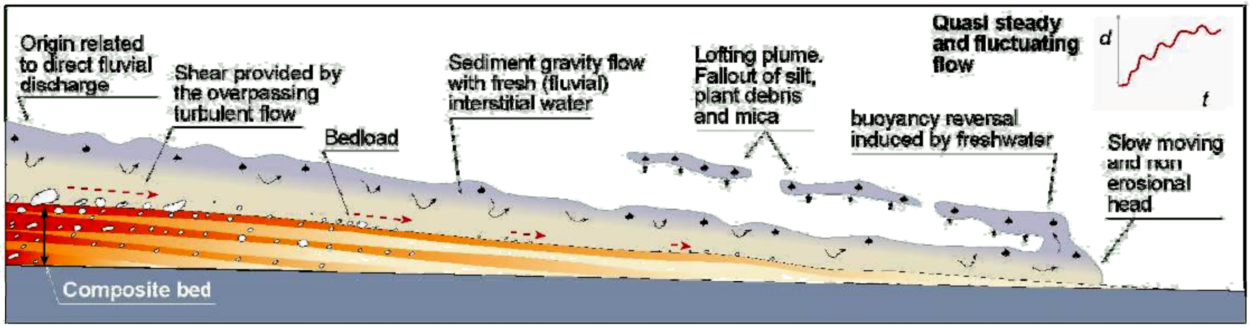

Figure 2: Main characteristics of long-lived hyperpycnal flows and their typical deposits. The complexity of these flows results in the accumulation of composite beds (Zavala et al., 2007a).

Facies analysis: a genetic approach

The basic classification schema used in this study is shown in Fig. 3 (Zavala et al. 2006b), 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. Consequently, bedload facies are characteristic of proximal positions. Three main categories are recognized, termed B1 (massive fine grained conglomerates), B2 (pebbly sandstones with asymptotic low angle 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. 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. Finest suspended materials are also lifted from the substrate, and settle down forming silt/sand couplets of great lateral extension (lofting rhythmites, Zavala et al 2006c). Facies analysis based on a genetic classification provides new perspectives to the paleoenvironmental understanding and the prediction of reservoir quality.

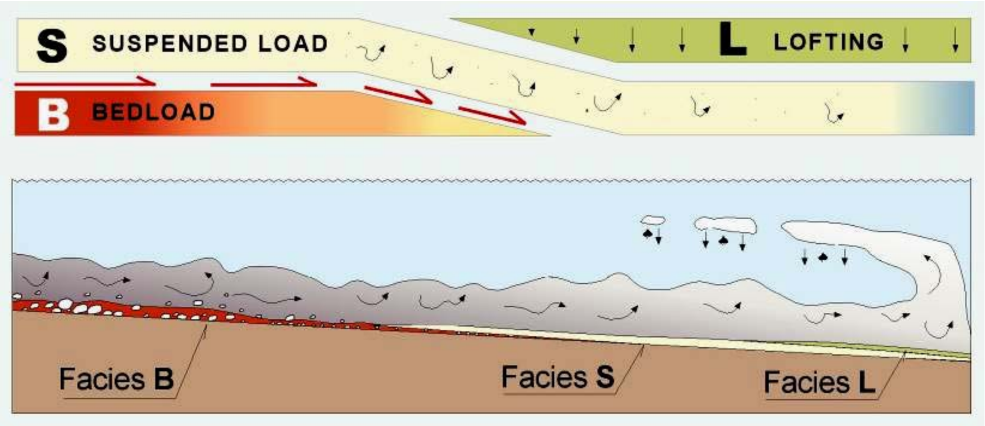

Figure 3. Basic conceptual diagram for facies analysis of hyperpycnal deposits with associated bedload in marine settings. Facies B include all those facies related to bedload processes developed at the base of an overpassing long-lived turbulent flow. Facies S correspond to the gravitational collapse of sand-sized materials transported in suspension by the turbulent flow (suspended load facies). Facies L are related to the fallout of fine grained materials lifted-up by the interstitial freshwater contained in the flow once it lost part of the sand-sized suspended load. After Zavala et al. (2006b).

Genetic indexes

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 (Zavala et al. 2007b). These indexes should be calculated individually for each studied locality.

The proximity index (Pt): The Pt index is a dimensionless number that measures how proximal the locality is 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. The proximity index can be calculated 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 hyperpycnal facies are considered.

The Pt index varies between 0 and 100. While greater the Pt index is, 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 intermediate positions in the system. 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 hyperpycnal system under study.

<u>The laterality index (Lt):</u> 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:

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

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.

<u>Ternary indexes:</u> In addition to the proximity and laterality indexes, ternary indexes and diagrams are useful to depict the different proportions between the three main facies categories used in the genetic analysis (B, S, and L facies, Fig. 4).

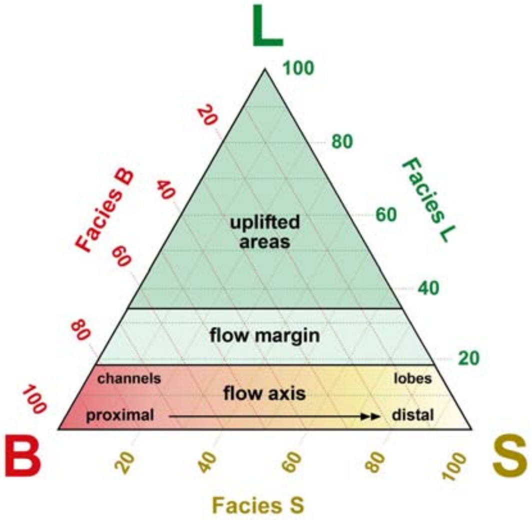

Figure 4: The use of ternary diagrams allows to plot the relationships between bedload, suspended load and lofting facies, and to show the position of the studied locality respect to the system as a whole. In a single well, ternary analysis can be useful to determine sedimentary trends (progradation/ retrogradation) between different depositional sequences.

B, S and L indexes are calculated comparing the total thickness of each category respect to the total thickness of hyperpycnal facies, in the form that B+S+L= 100. The ternary diagrams allow to define several “fields” (uplifted areas, flow margin, flow axis, proximal channels, and distal lobes, Fig. 3) which are useful to analyze the position of the well respect of the hyperpycnal system considered as a whole.

Discussion

The use of genetic indexes in hyperpycnal systems allow to determine source areas and to map and predict the distribution of coarse grained clastic facies (Marcano et al., this volume). Nevertheless, the analysis of genetic indexes must be done within a sequence stratigraphic framework in order to analyze data related to the same stratigraphic (coeval) interval. In the case of core studies the analyzed interval should be representative of the sequence under consideration.

Acknowledgement

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