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Sedimentological indexes:
a new tool for regional studies of hyperpycnal systems

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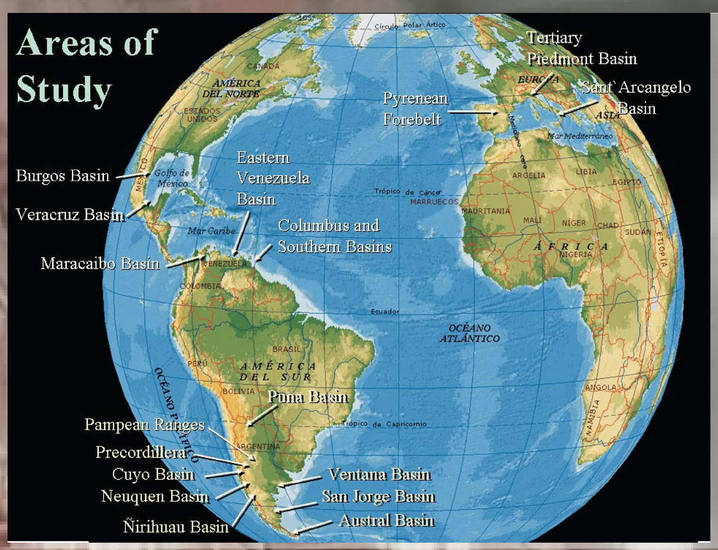
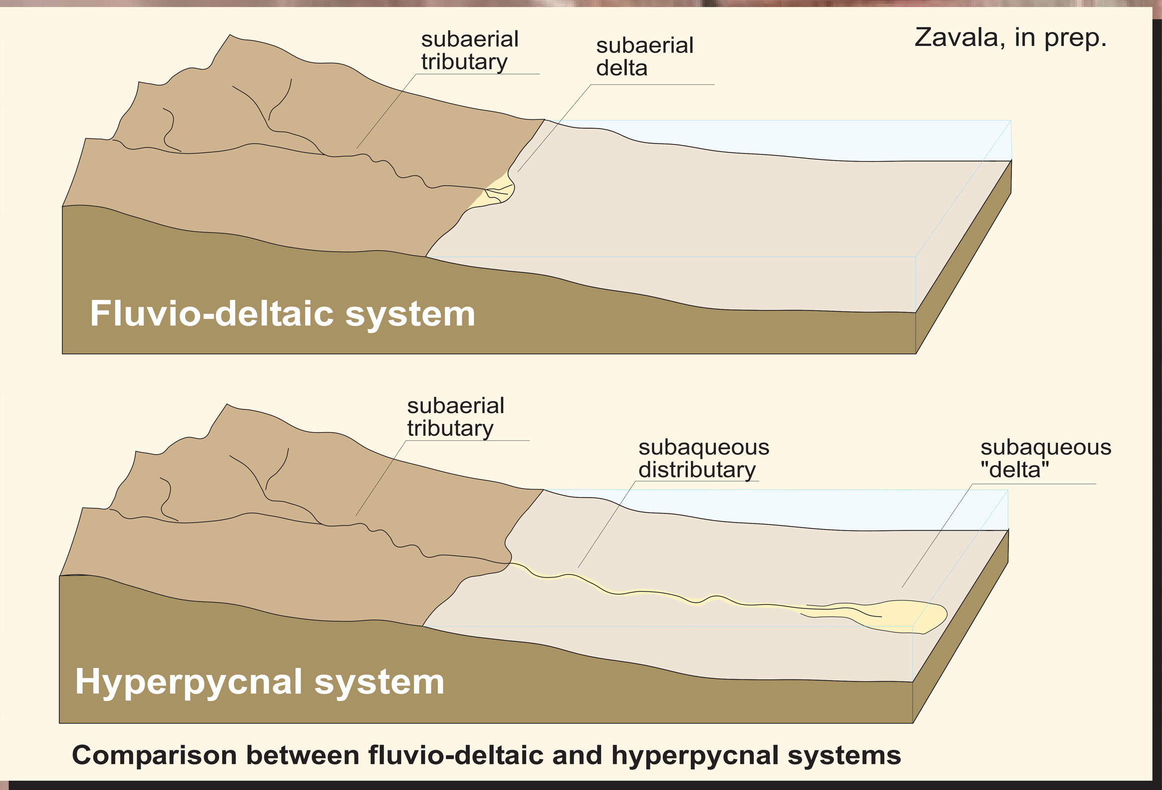
OBJECTIVES

- To discuss the importance of hyperpycnal procesess in controlling the delivering of huge volumes of clastics to contemporaneous marine and lacustrine basins.
- To introduce a new methodology for subsurface mapping of hyperpycnal deposits from core studies



DATA SET

This contribution is based in more than 20 years of studies of ancient sediment gravity flows deposits in several sedimentary basins of South America and Europe.



Comparison between fluvio-deltaic and hyperpycnal systems

HYPERPYCNAL SYSTEMS

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 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.

HYPERPYCNITES:
diferences with "classic" turbidites

Hyperpycnites Mulder et al. (2003) are turbidites originated from a land-derived sediment gravity flow having a low density intertitial fluid (freshwater). Conceptually all hyperpycnal flows are turbidity flows and underflows, but not all underflows and turbidity flows are hyperpycnal in origin. Hyperpycnal flows refers only to those sediment gravity flows originated in land from a fluvial discharge. Hyperpycnal flows can be short or long lived depending on the nature of the associated fluvial system. Commonly, short lived hyperpycnal flows (minutes to hours) are smaller, and associated with high relief catchment areas (e.g. Alluvial fans). Long lived hyperpycnal flows (days to weeks) on another hand are associated to large and low relief drainage areas. Classical (Bouma-like) turbidites differ with hyperpycnites in several fundamental details:

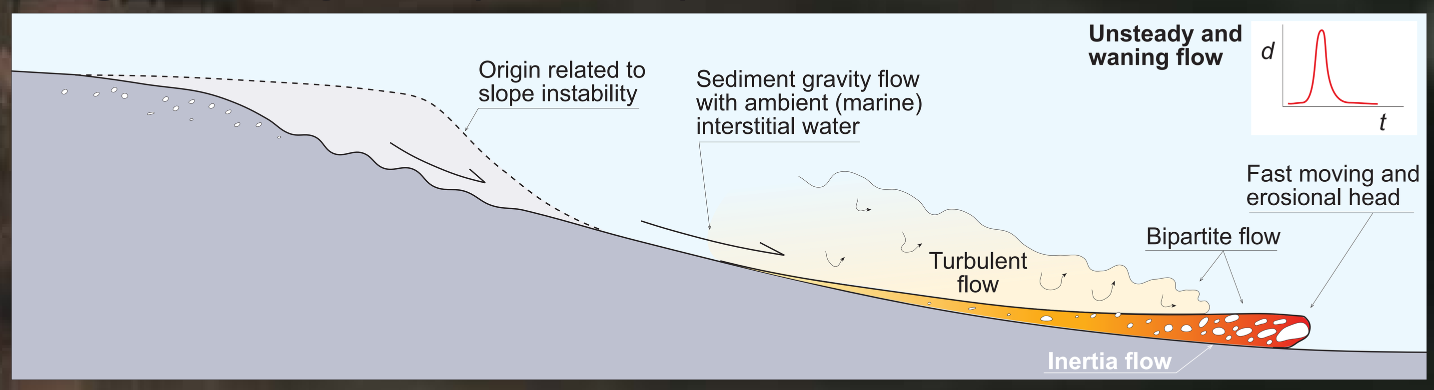
Classic turbidites:

- have an origin related to slope instability often triggered by earthquakes or major storms.
- are sediment gravity flows with an intertitial fluid composed of marine (ambient) waters.
- the flow is essentially bipartite (Sanders 1965; Mutti et al. 1999) with a lower fast moving inertia flow followed by a slow moving turbulent flow.
- greater velocities are achieved close to the head (Kneller & Buckee 2001)
- erosion and deposition occur in the front of the flow.
- a typical turbidity bed is normally graded with a finning upward trend

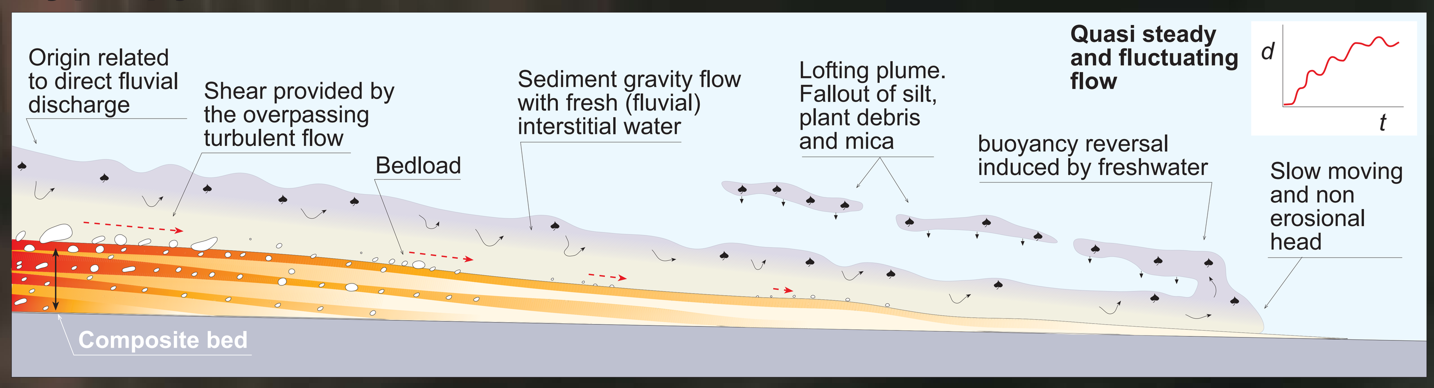
Hyperpycnites:

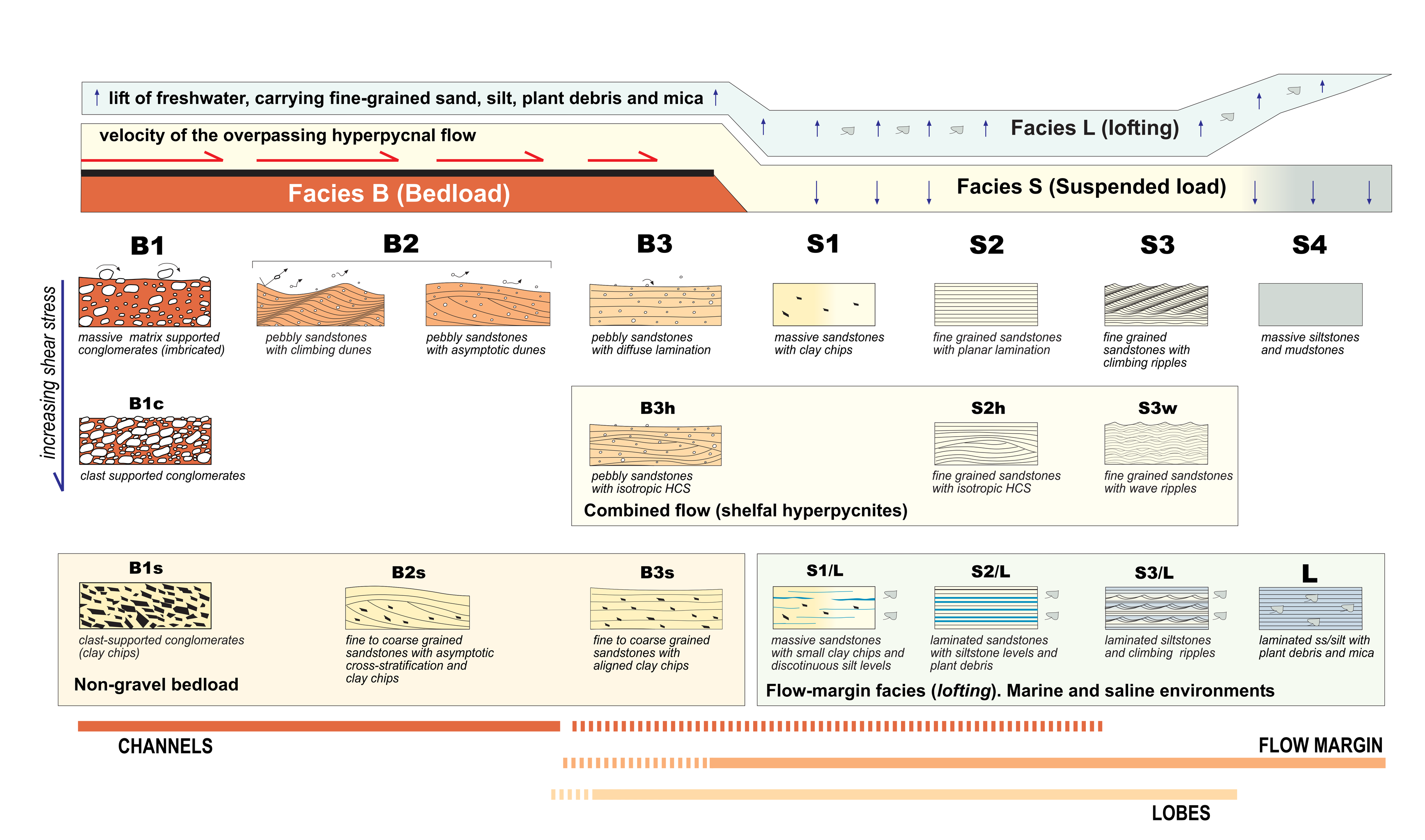
- have an origin related to a direct fluvial discharge
- are sediment gravity flows with a less dense interstitial fluid (freshwater) respect to marine waters
- the flow is turbulent, and can have bedload inherited from the original discharge or loaded from erosion on the shelf
- greater velocities are achieved in the main body. The leading head is slow moving and very sensitive to the subaqueous topography
- erosion and deposition occur in the main body of the flow (De Rooij and Dalziel 2001; Peakall et al. 2001).
- a typical hyperpycnal bed is a composite bed internally showing gradual facies changes related to flow variations

Surge turbidity flow (classical)



Hyperpycnal flow





FACIES TRACT

The basic classification schema used in this study is based in the distinction of three main facies categories related to bedload (B), suspended load (S) and lofting (L) facies (Zavala et al., 2006b). 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). 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 L (lofting) relates to the buoyancy reversal provoked by the lift-up of a less dense fluid (in the case freshwater) on marine environments. Facies analysis based on a genetic classification provides new perspectives to the paleoenvironmental understanding and the prediction of reservoir quality.

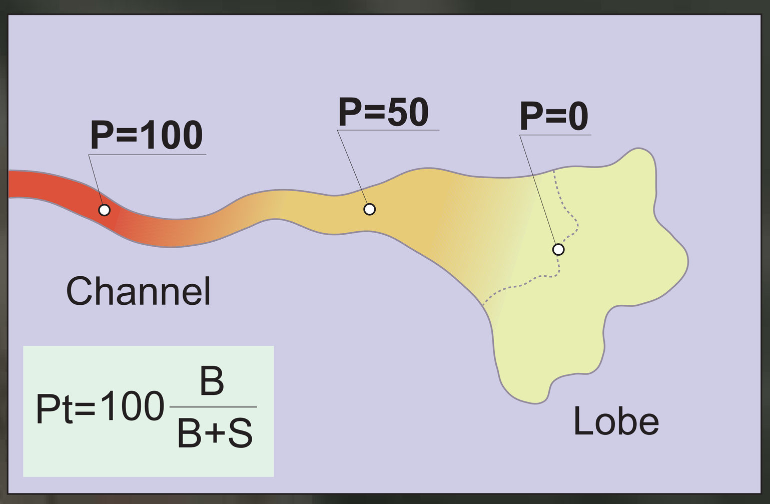
SEDIMENTOLOGICAL INDEXES

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. 2007). These indexes should be calculated individually for each locality under study.

The proximity index (Pt) 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. 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.



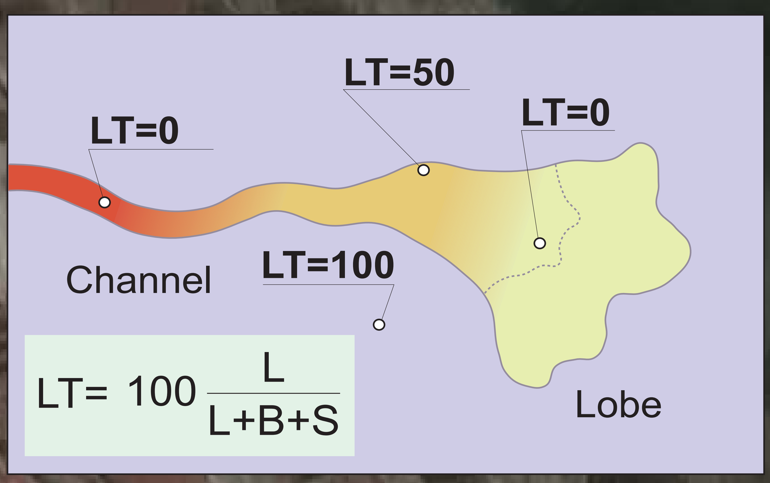
The Pt index varies between 0 and 100. The greater the Pt index is, the more proximal the considered location will be within the hyperpycnal system. In fact, Pt indexes between 100 and 50 characterize proximal system areas, while Pt indexes comprised between 50 and 0 suggest medium system areas.

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.

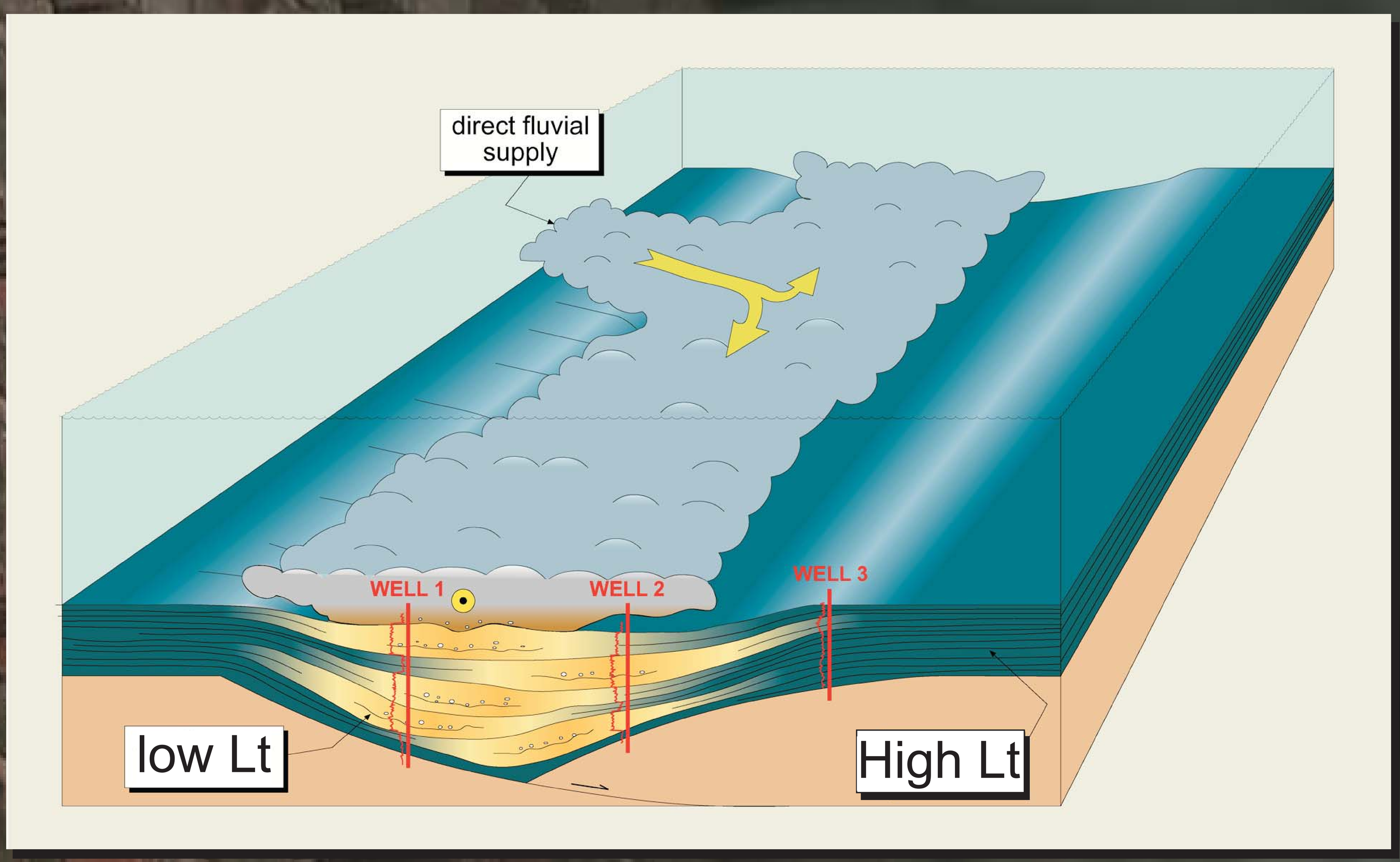
Laterality index (Lt): Because of the gravity nature of the hyperpycnal flow, coarse grained facies are very sensitive to any subaqueous topography. Facies B and S tend to develop infilling the lowermost positions of the submarine landscape. On the contrary, lofting facies mostly characterize relatively 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 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.

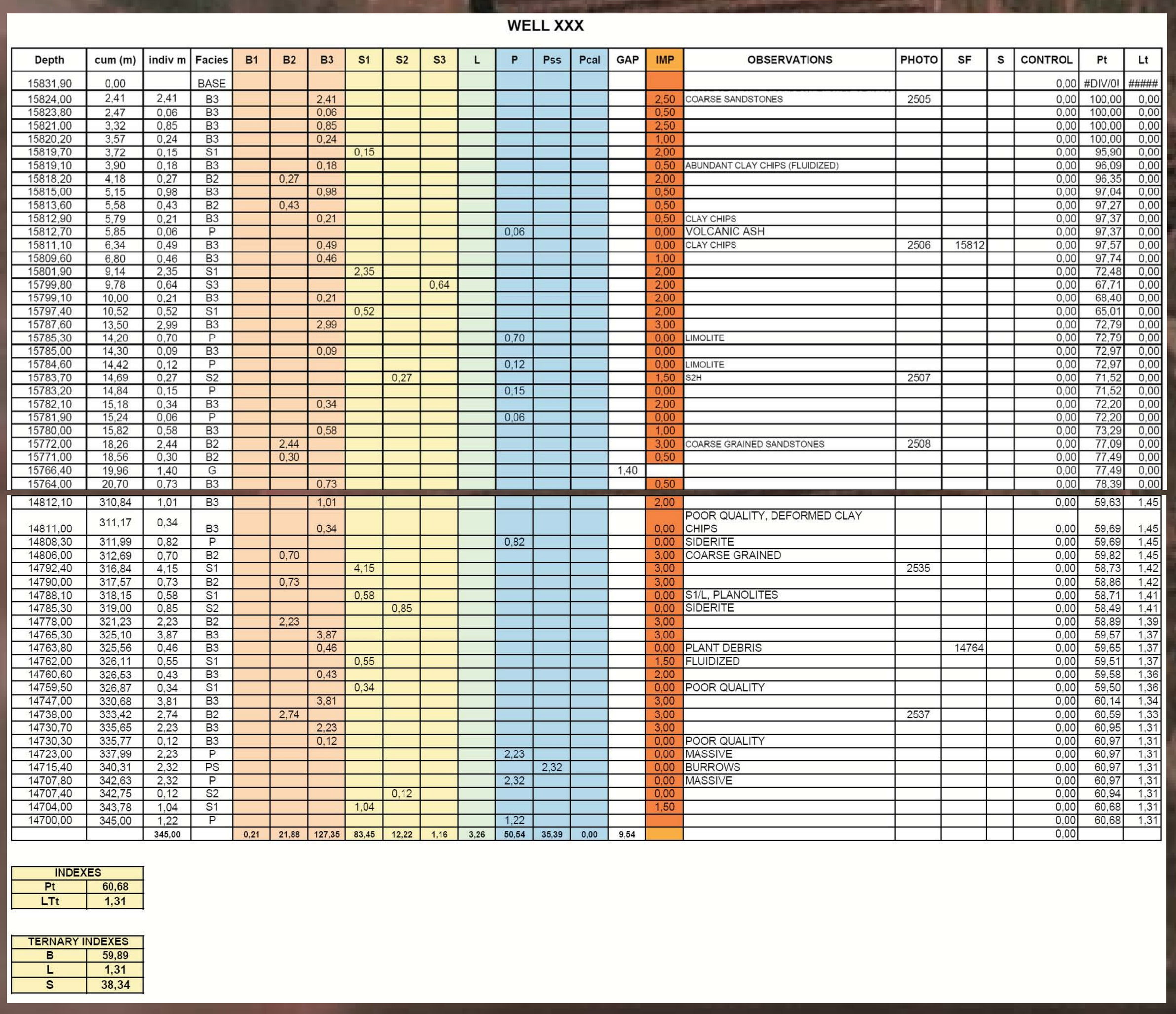


The Lt index is useful to delineate the location of synsedimentary-growing tectonic structures in the subsurface. In the main depocenters affected by coarse grained hyperpycnal sedimentation, the laterality index tend to be low, typically less than 15, while lateral uplifted areas has laterality indexes that exceeds 35.

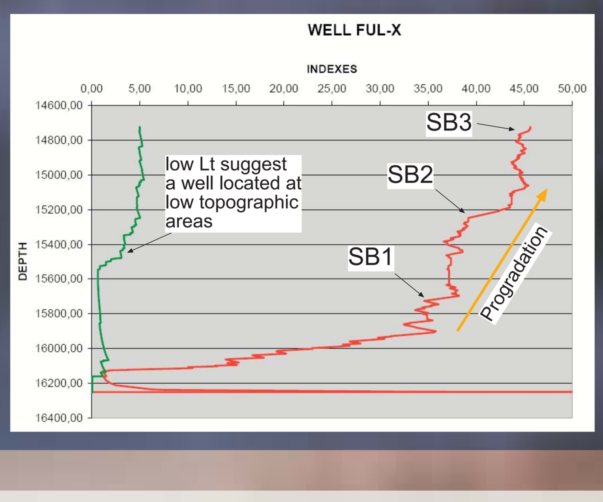


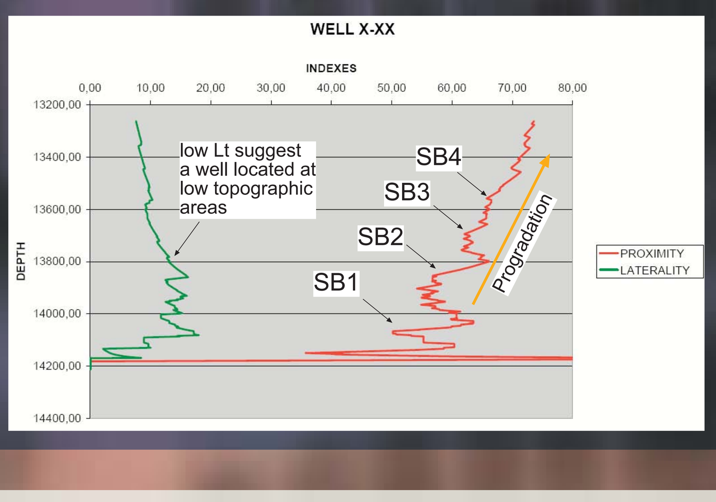
EXCEL SHEETS

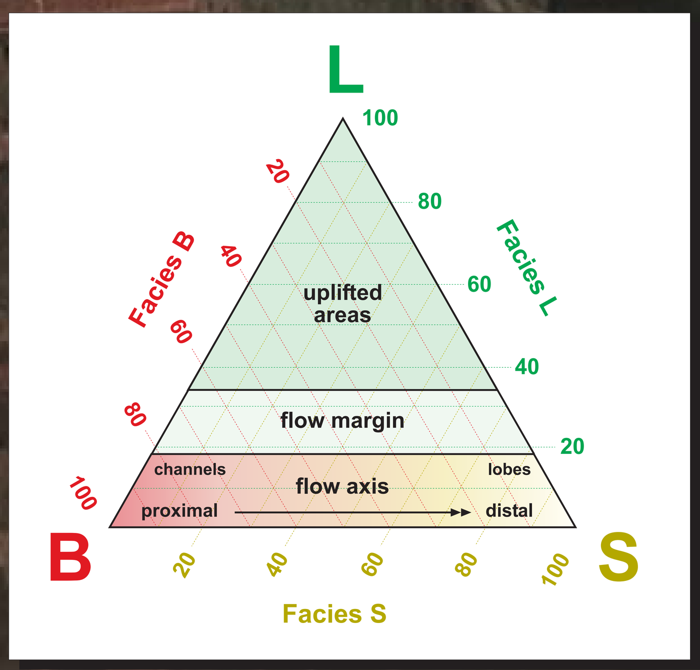
Determination of sedimentological indexes for facies mapping can be optimized using specially designed Excel sheets that allow the description and processing of a large amount of core data. This Excel sheet automatically calculates sedimentological and ternary indexes, and also allows the construction of facies logs and ternary diagrams.

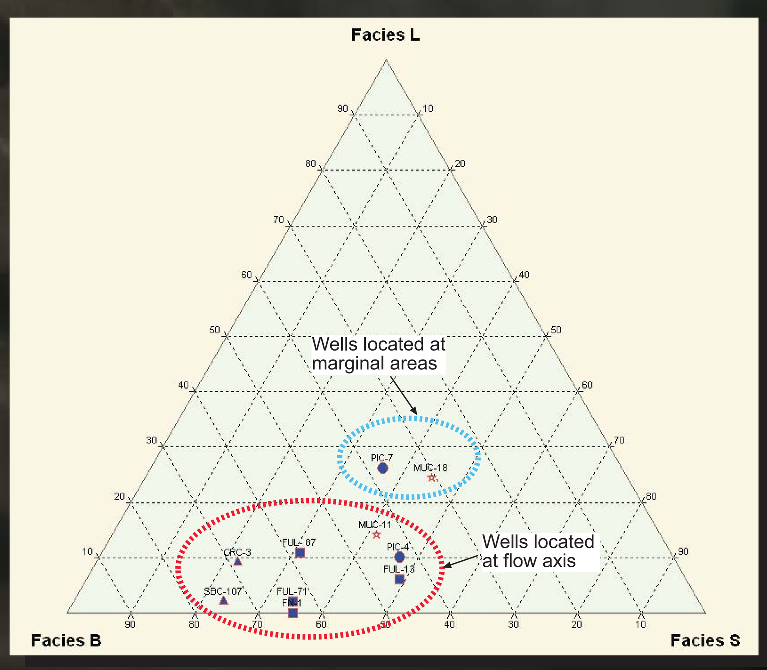


In the Merecure Gp (Oligocene, Marurin Basin, Venezuela) Abrupt changes in proximity and laterality indexes often suggest sequence boundaries. In the example, well X-XX is proximal respect to the well FUL-X. (vertical scales are different)

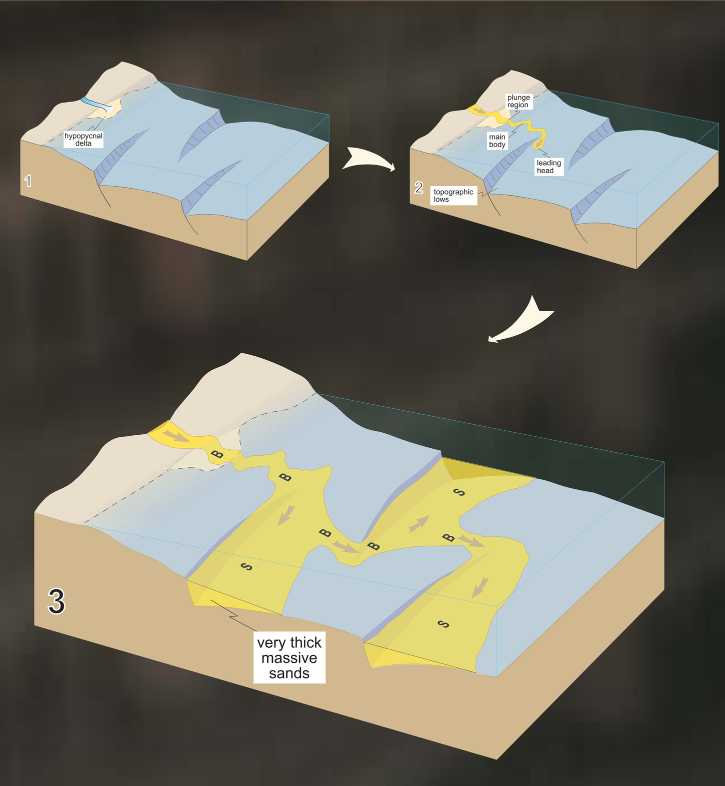


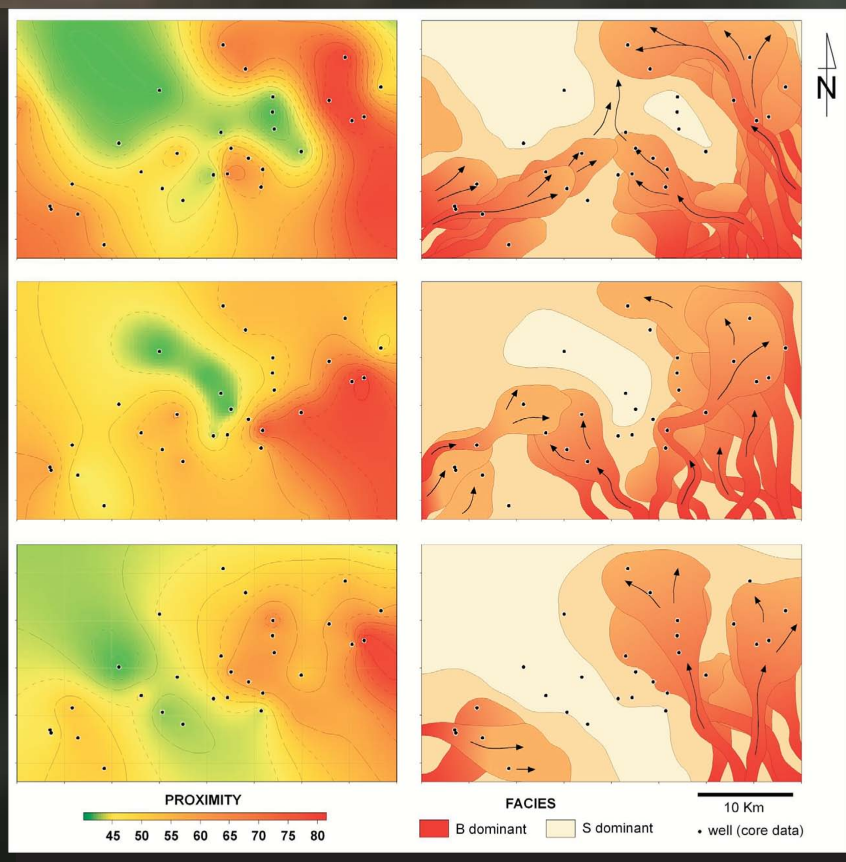






Ternary diagrams are useful to depict the different proportions between the three main facies categories used in the genetic analysis (B, S, and L facies). B, S and L indexes are calculated comparing the total thickness of each category respect to the total thickness of hyperpycnal facies, in the form that B+S+L= 100. The ternary diagrams allow to define several "fields" (uplifted areas, flow margin, flow axis, proximal channels, distal lobes) which are useful to analyze the position of the well respect of the hyperpycnal system considered as a whole.





CONCLUSIONS

The use of sedimentological 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 congress). Nevertheless, the analysis of genetic indexes must be done within a sequence stratigraphic framework in order to analyse 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.

Acknowledgements

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