Intrabasinal and Extrabasinal Turbidites: Origin and Distinctive Characteristics*

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Abstract

After its original conception, turbidites were related to re-sedimentation processes in deep waters. Sediments initially stored in littoral/shallow marine environments were periodically transferred (or re-sedimented) into the inner basin by slope instability. Since these turbidites originate within the marine basin, the resulting sediment gravity flows are intrabasinal turbidites. More recently, an increasing number of evidences show that turbidites commonly originates from the direct discharge from rivers in flood. These turbidites result from relatively dense turbulent sediment suspensions entering the sea as hyperpycnal flows. Since these turbidites originate in the continent, they are extrabasinal turbidites. The deposits of intrabasinal and extrabasinal turbidites have diagnostic features allowing a clear differentiation of them. Intrabasinal turbidites are dominated by surge-like flows, and commonly initiate from a cohesive debris flow that progressively dilutes and transform into a granular and finally a turbulent flow. Since intertidal water is ambient water, lofting is not possible. Additionally the dynamics at flow head washes the turbulent flow from light materials resulting in normally graded beds without plant remains. On the contrary, extrabasinal turbidites are fully turbulent flows with interstitial freshwater, driven by a relatively dense and sustained river discharge. Depending on the grain-size of suspended materials, the resulting hyperpycnal flow can be muddy or sandy. Sandy hyperpycnal flows also can carry bedload resulting in sandy to gravel composite beds with sharp to gradual internal facies changes and plant debris, laterally associated with lofting rhythmites. Lofting occurs because flow density reversal due to the buoyant effect of freshwater when a waning turbulent flow loses part of the sandy suspended load. On the contrary, muddy hyperpycnal flows are loaded by a turbulent suspension of silt and clay. Since the concentration of silt and clay do not decrease with flow velocity, muddy hyperpycnal flows will be not affected by lofting and the flow will remain attached to the sea bottom until its deposition. The last characteristics commonly result in cm-thick graded shales disposed over an erosive base with dispersed plant debris and displaced marine microfossils. We interpret that most of the shales of the Jurassic Los Molles and Vaca Muerta formations in the Neuquen Basin (Argentina) were accumulated in this way.

Selected References

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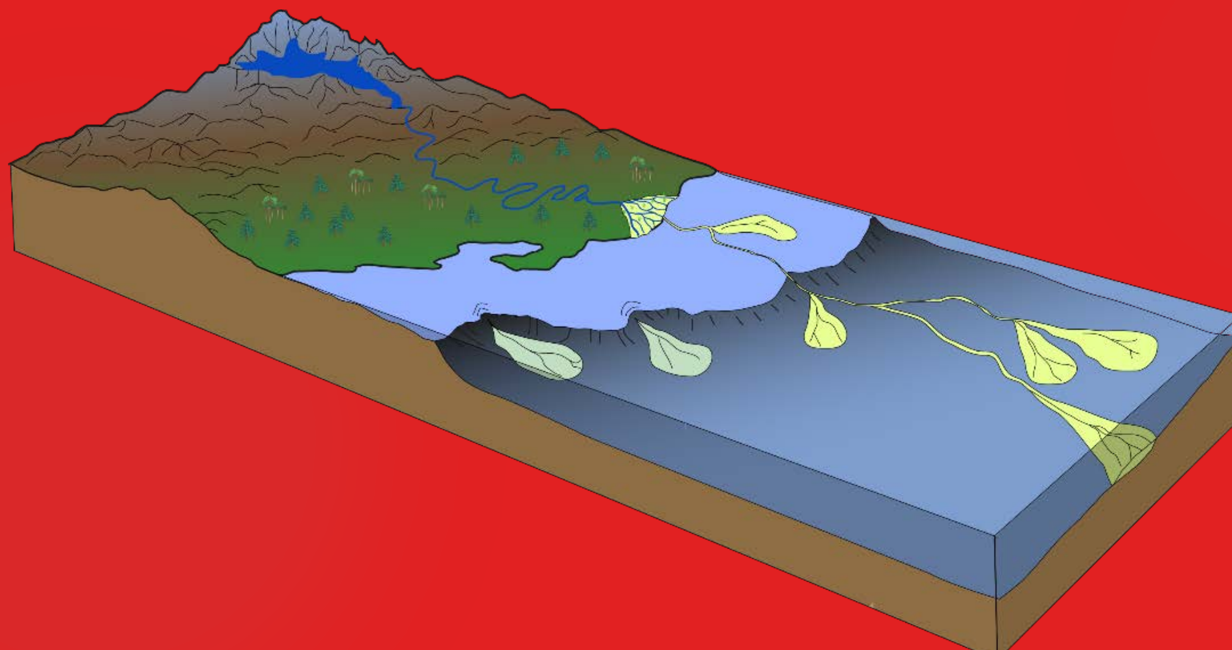
INTRABASINAL AND EXTRABASINAL TURBIDITES: ORIGIN AND DISTINCTIVE CHARACTERISTICS



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Objectives

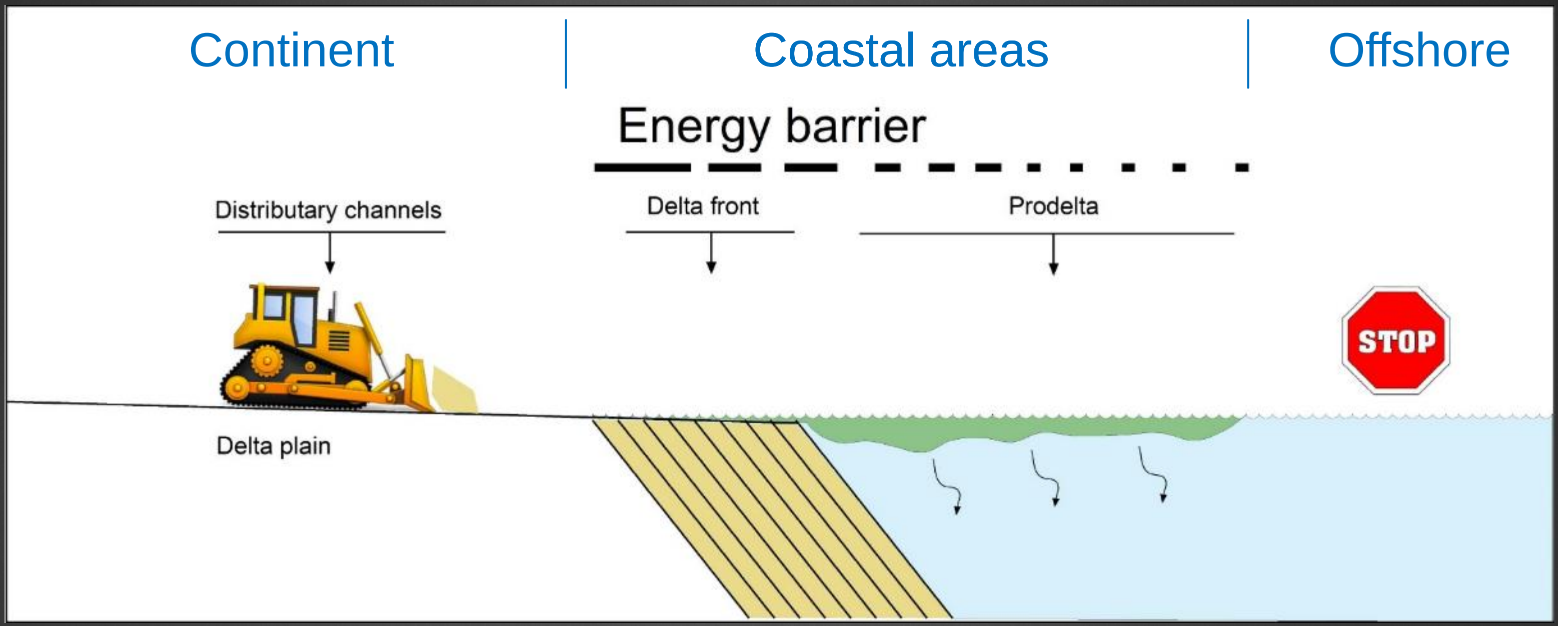
- To outline **the importance of turbidites** as an efficient mechanism for **transferring clastic materials into the basin**

- To discuss the **differences between intra and extrabasinal turbidity currents**

- To introduce and discuss some **distinguishing diagnostic criteria** for the **recognition of intrabasinal and extrabasinal turbidity current deposits**

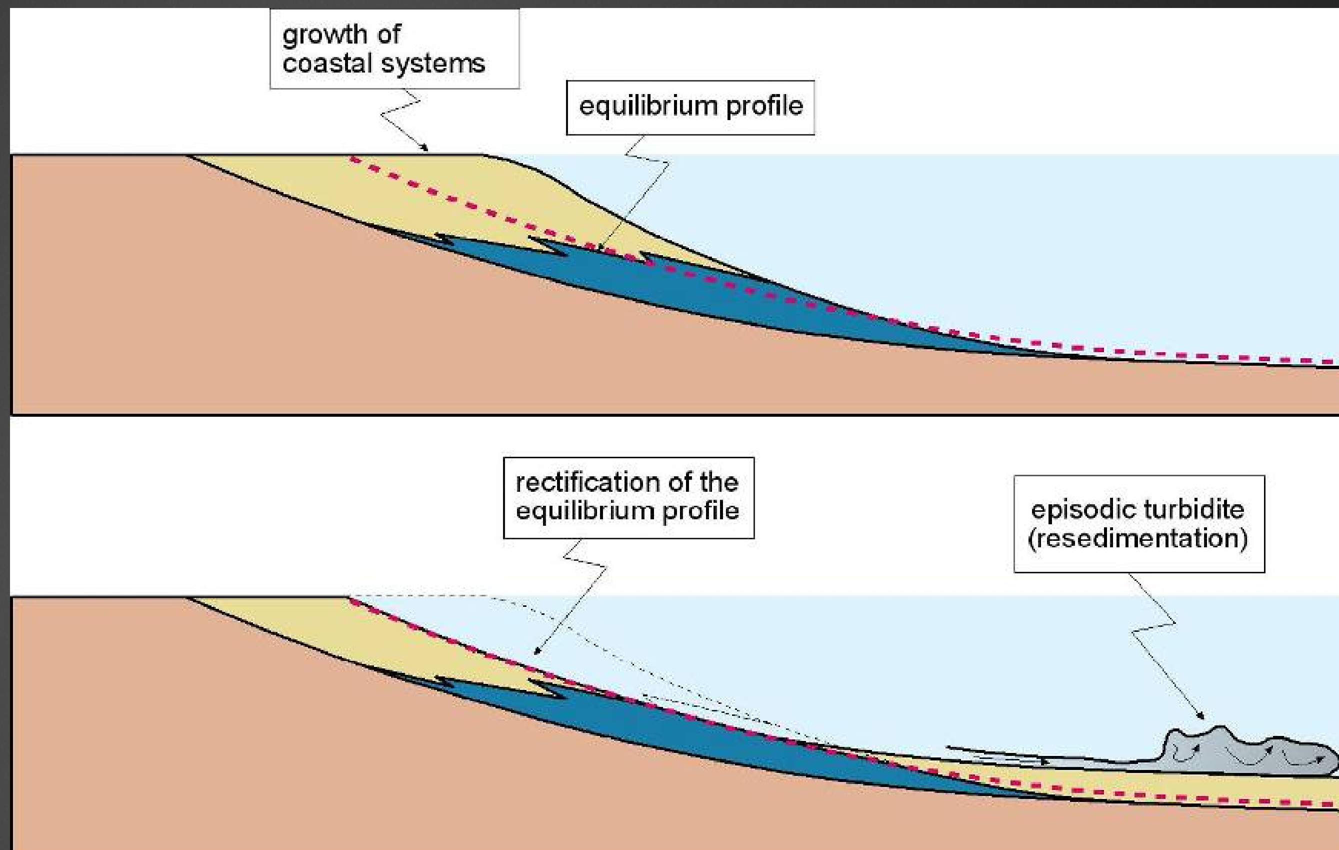
The energy-barrier paradigm

Sir John Murray (1841-1914)



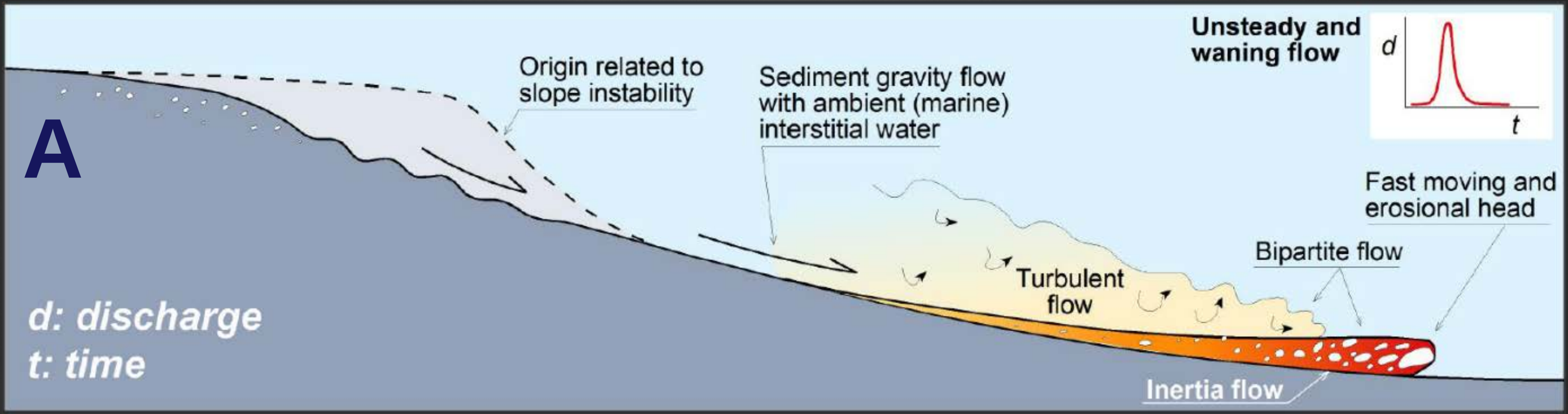
- ✓ Coastal areas **dissipate the energy**
- ✓ Coarse-grained materials **accumulate in continental or littoral environments**

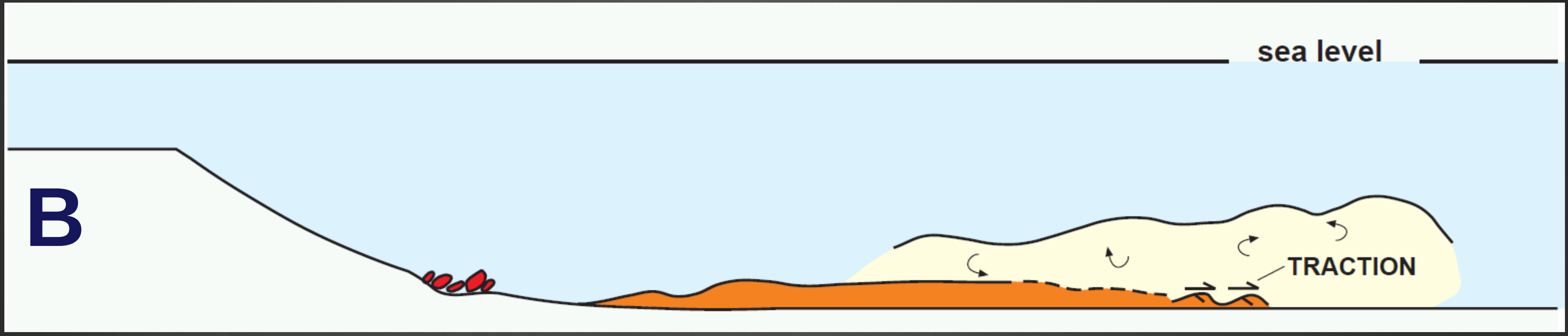
Carlo Ippolito Migliorini
(1891-1953)



The origin of turbidites as a resedimentation of coastal deposits

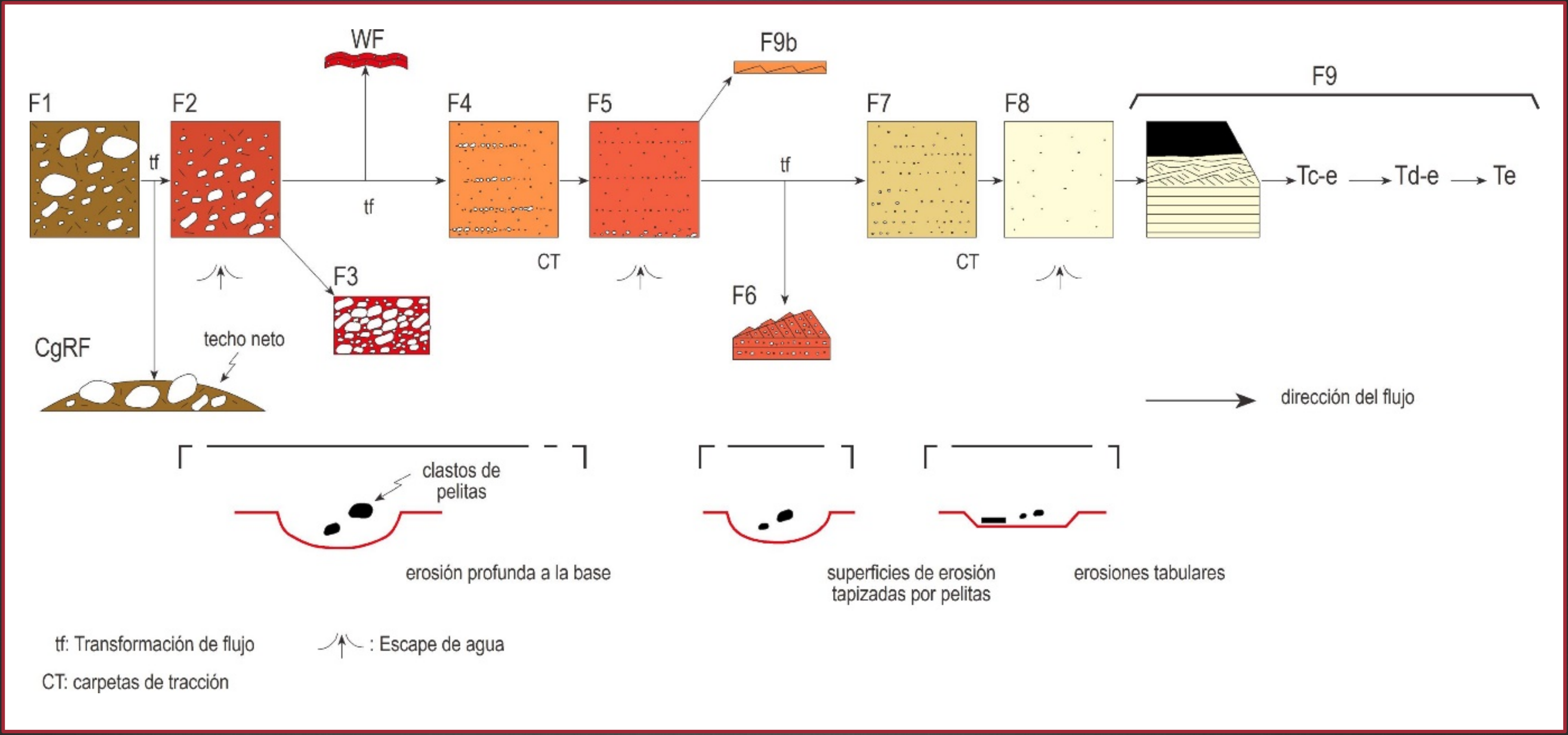
Intrabasinal turbidity currents





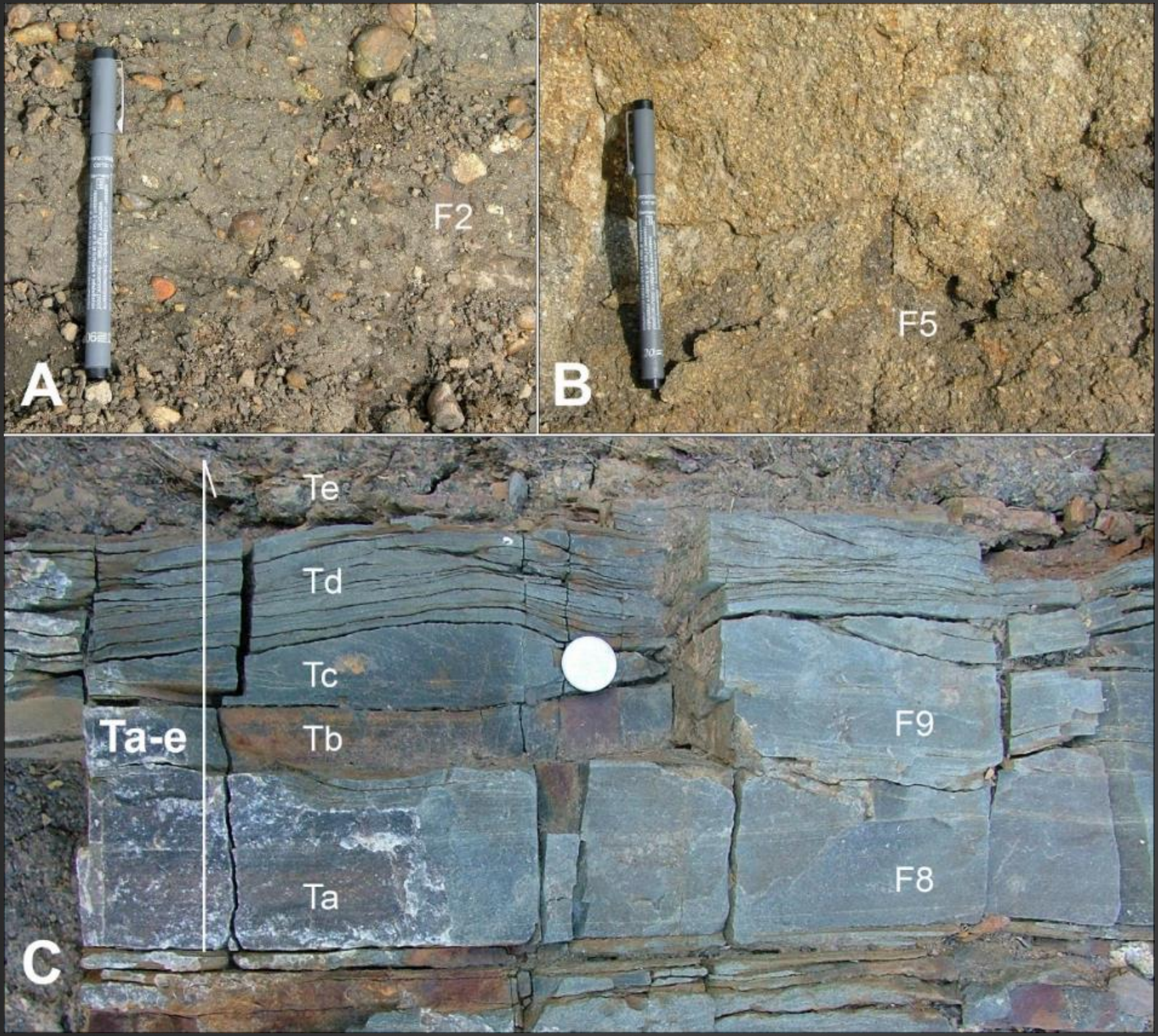
A: Main components of an Intrabasinal turbidity current, originated from slope destabilization. After Zavala et al., 2011. B: Diagram showing the transformation of a granular flow into a low-density turbidity current. After Mutti *et al.,* 1999.

Intrabasinal turbidity currents



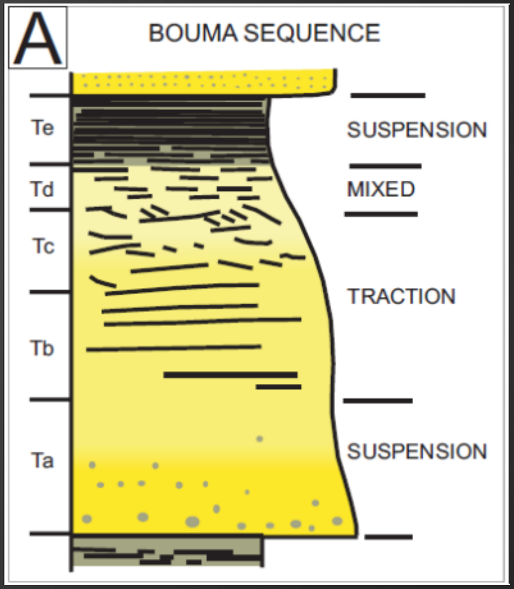
Facies tract showing the genetic interpretation of intrabasinal turbidity current deposits. After Mutti 1992.

Intrabasinal turbidity currents



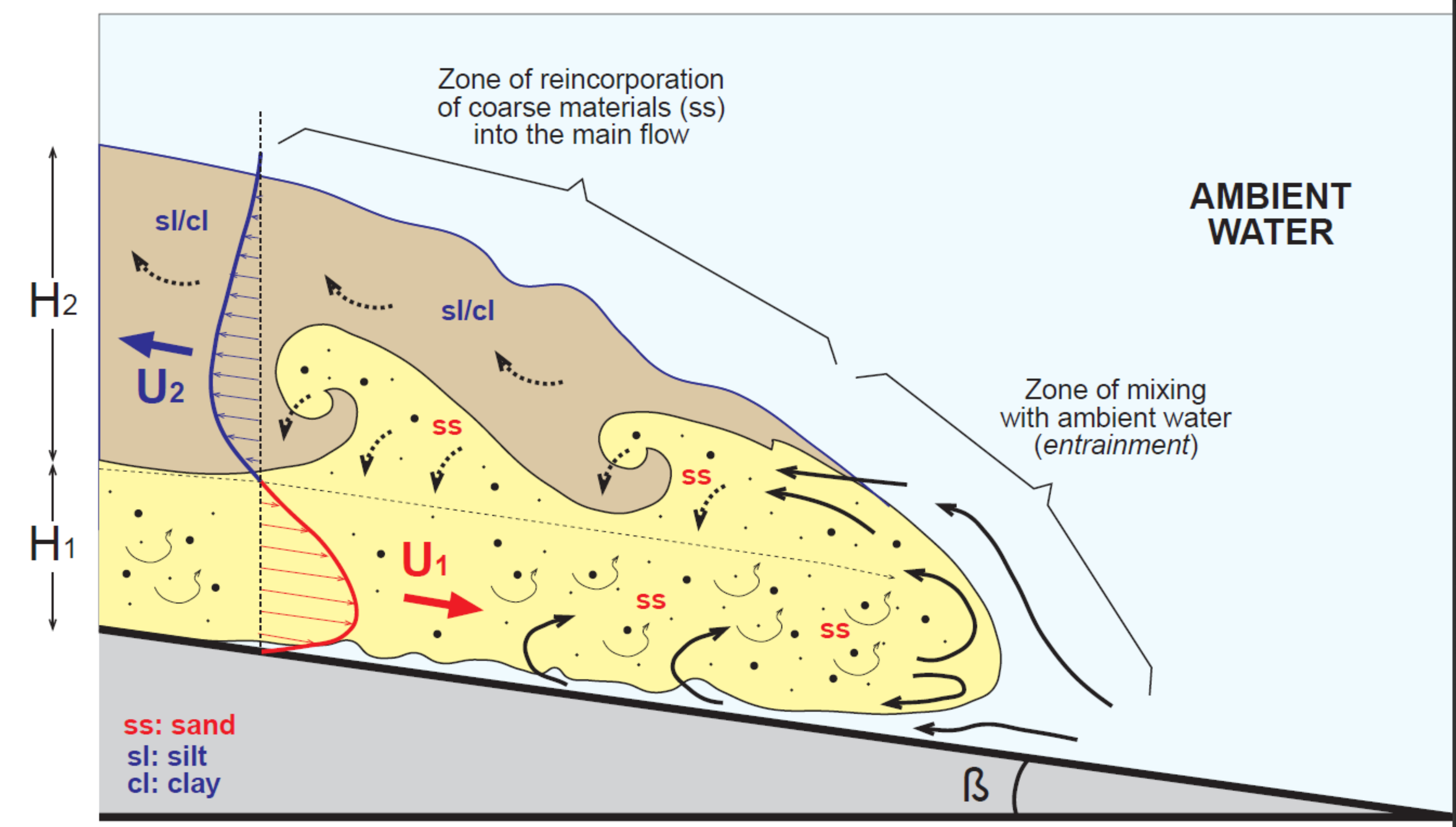
Granular flow deposits

Turbidity current deposits

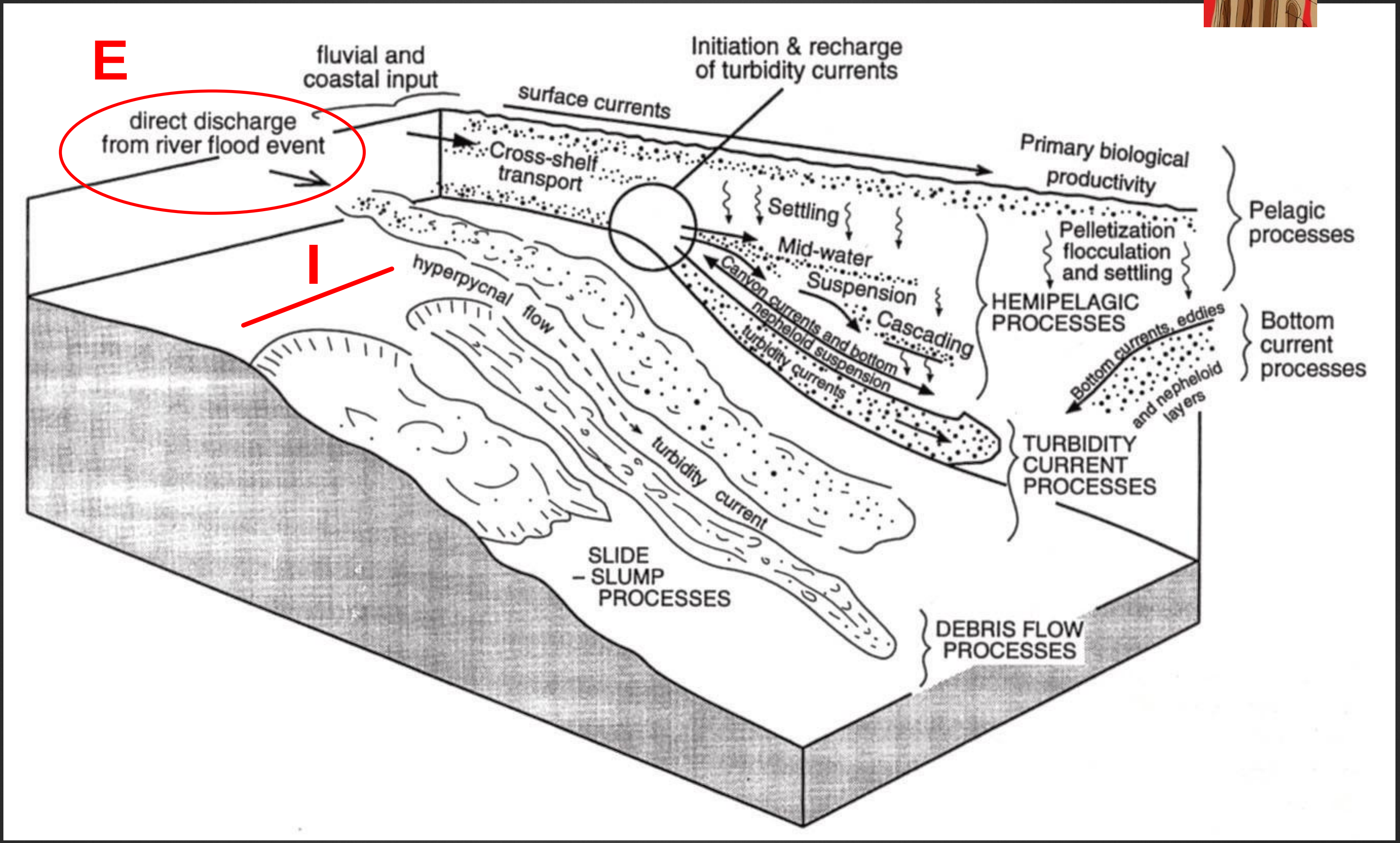


Slatt, 2006

Intrabasinal turbidity currents

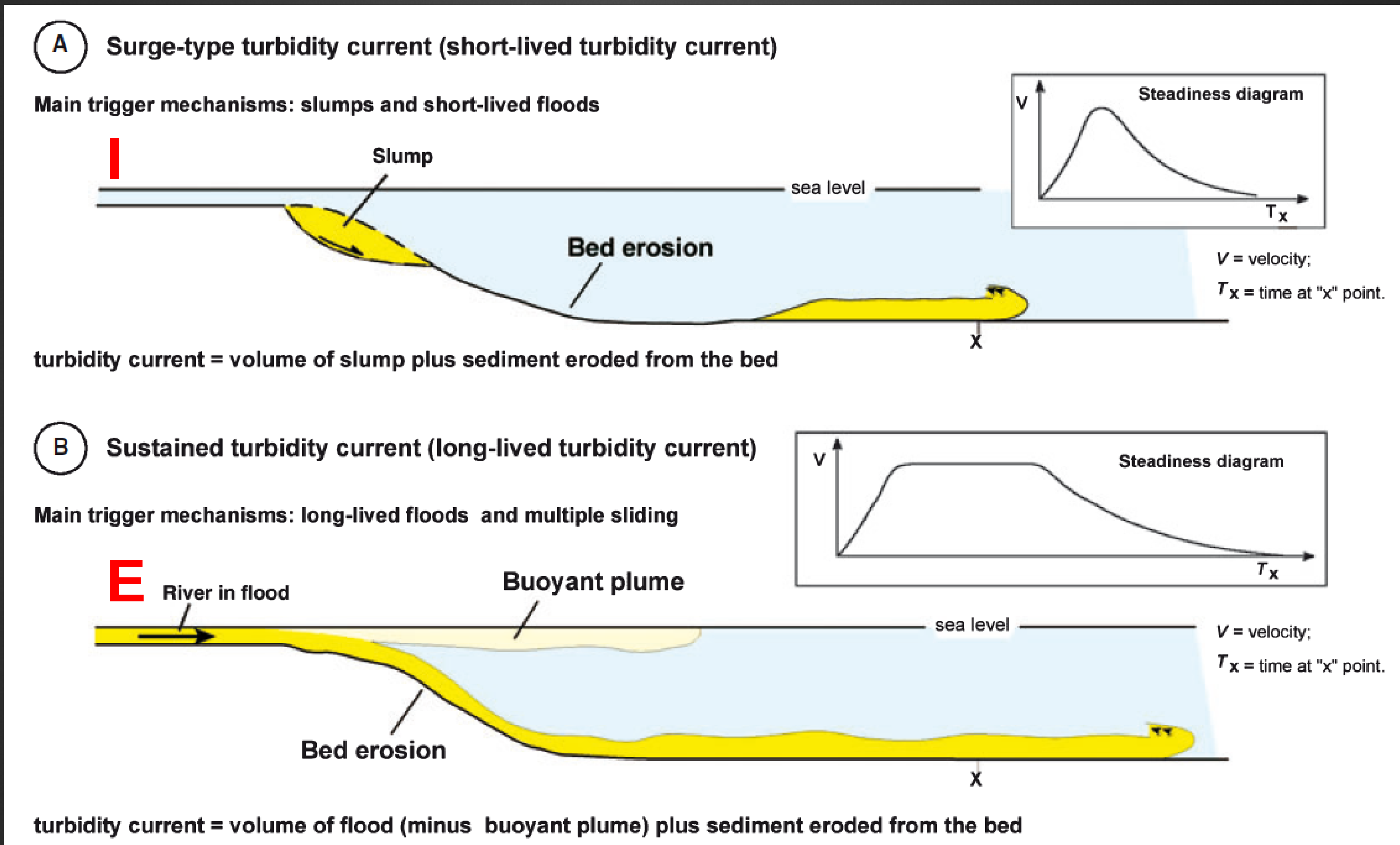


Detail of the head of an Iintrabasinal turbidity current. Note that fine-grained and lighter materials are not reincorporated in the main flow and will remain in suspension, being derived to the flow tail by the return current (U2). Modified from Simpson, 1987.



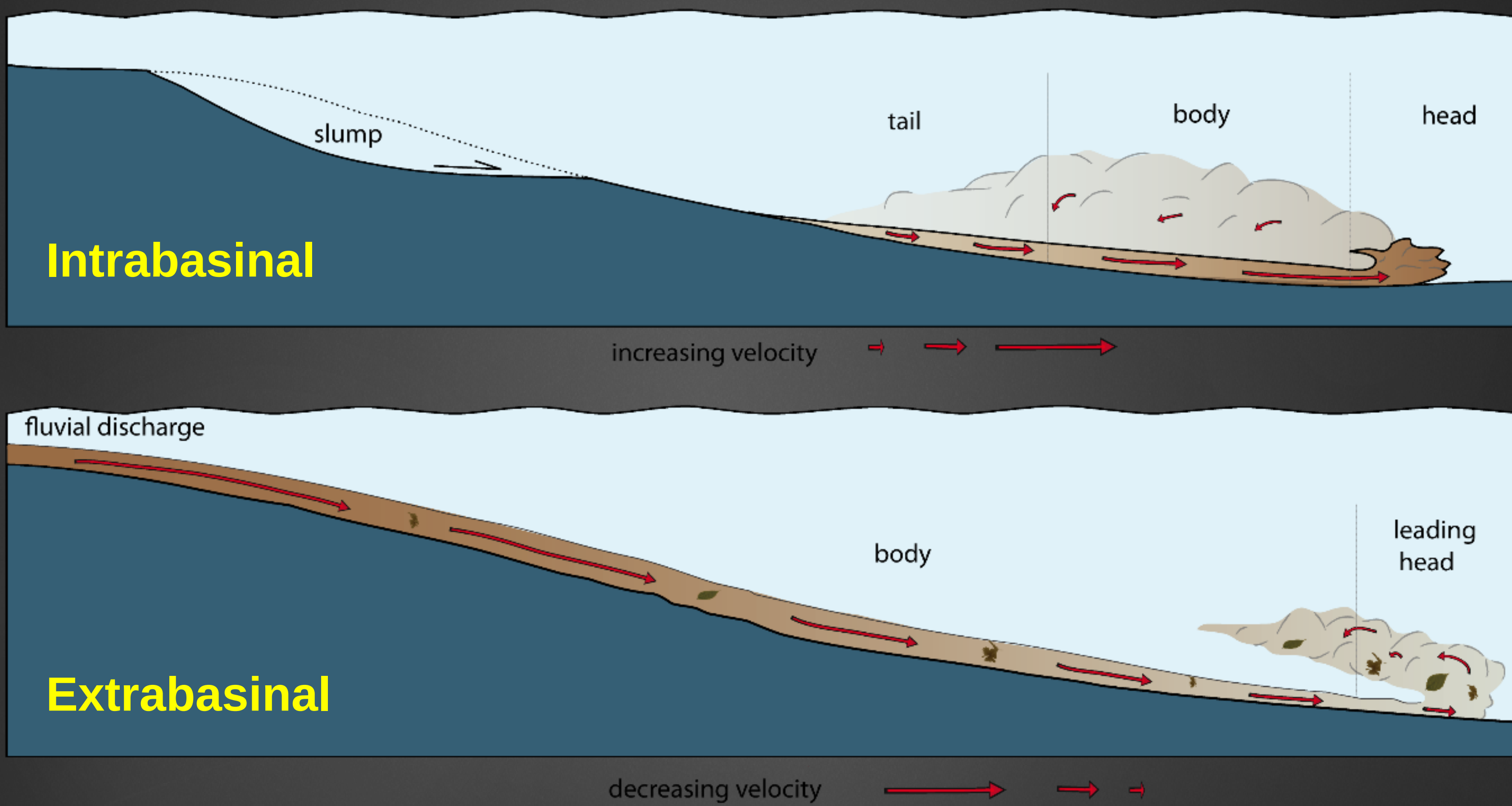
Stow *et al.*, 2000

Intrabasinal and extrabasinal turbidity currents



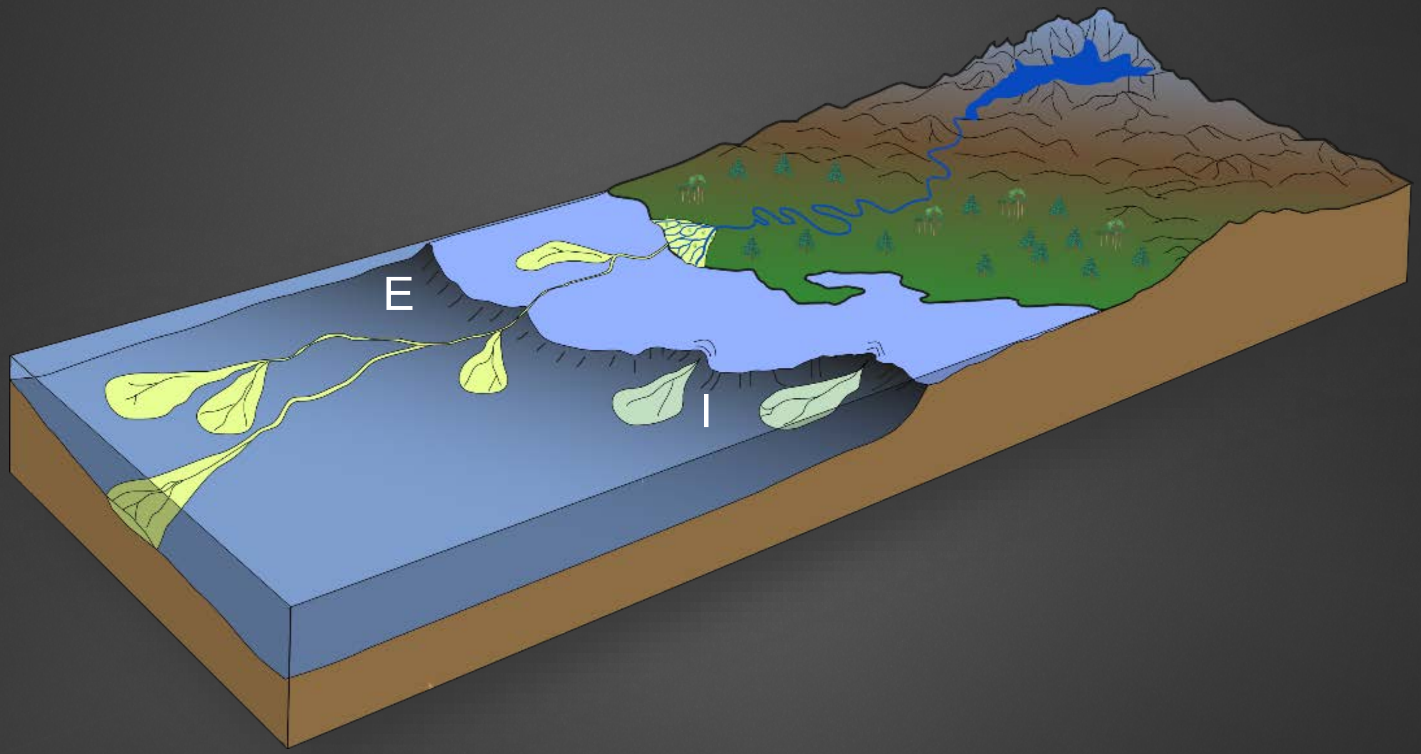
Mutti et al., 1999

Intrabasinal and extrabasinal turbidity currents



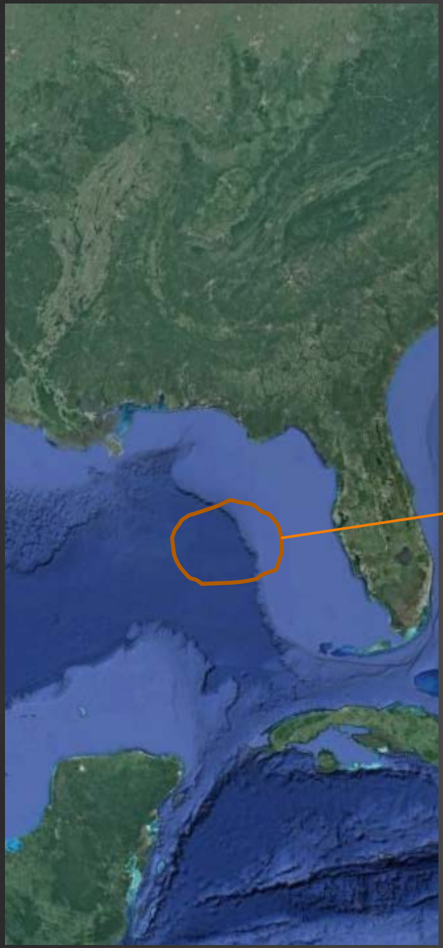
Comparison of the velocity profile between intrabasinal (I) and extrabasinal (E) turbidity currents. After Zavala et al., 2012a.

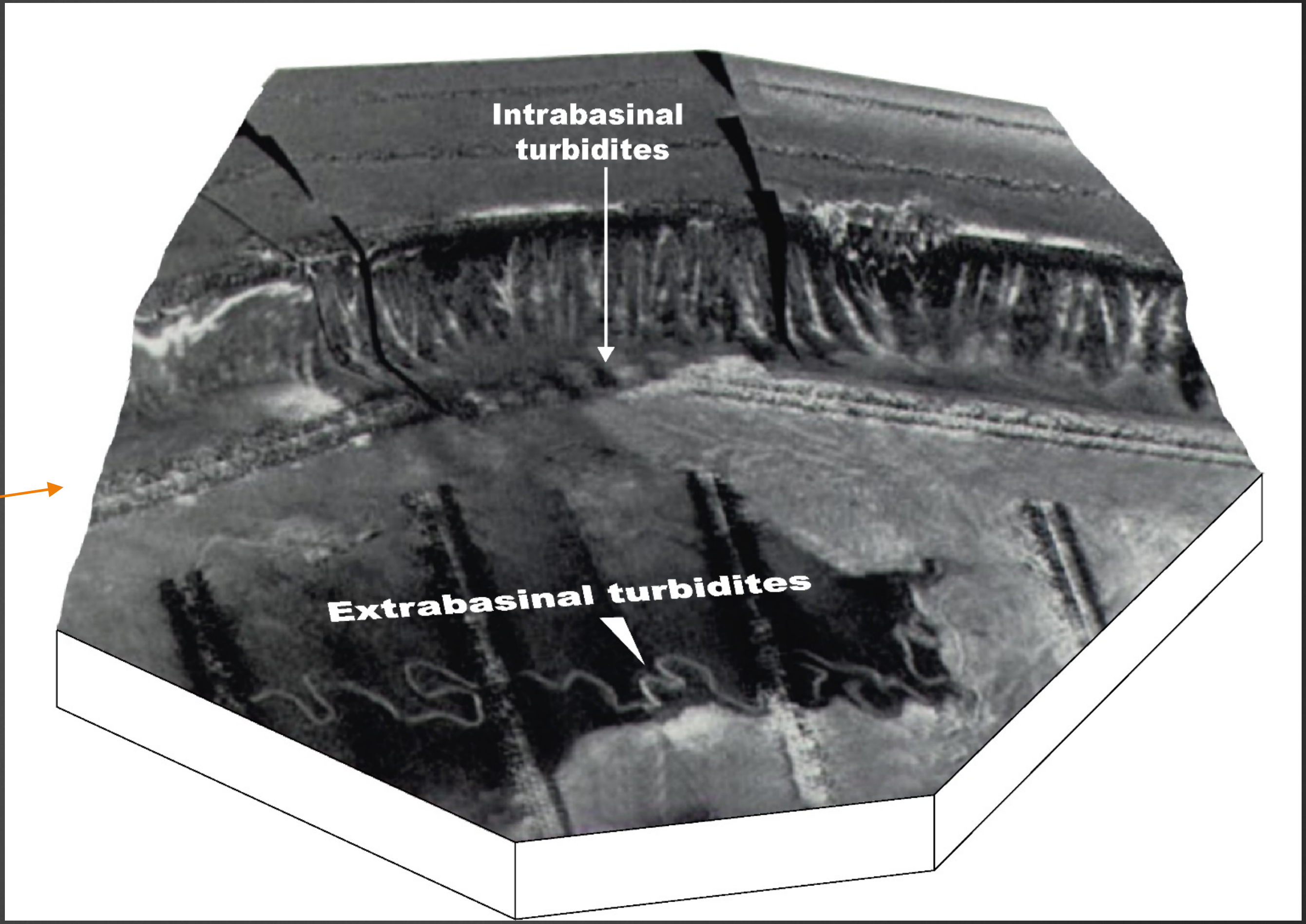
Intrabasinal and extrabasinal turbidites



Block diagram showing the occurrence of intrabasinal (I) and extrabasinal (E) turbidites. Note that extrabasinal turbidites receive a direct supply from rivers in flood, and can accumulate shelfal or deep marine deposits.

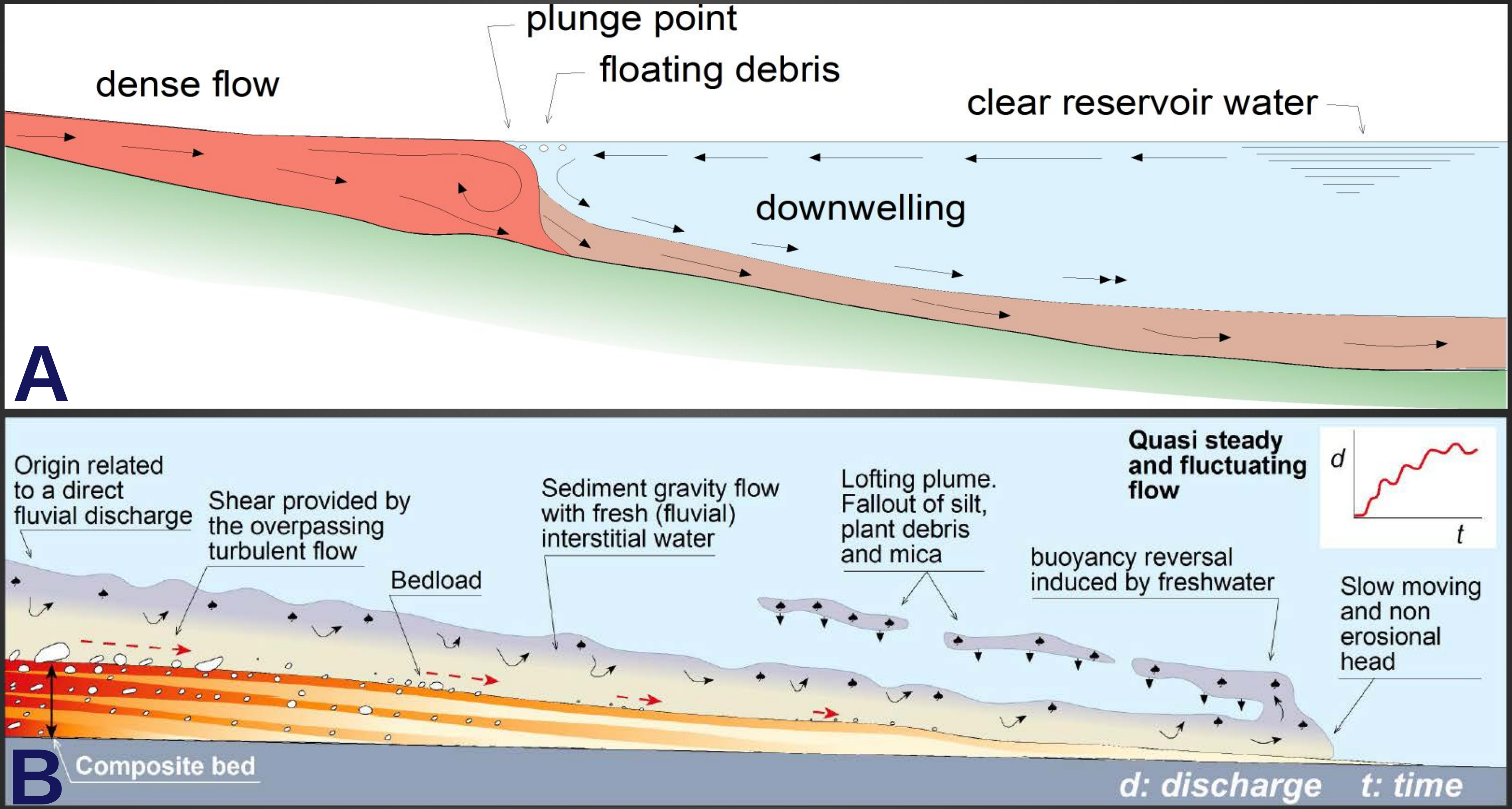
Intrabasinal and extrabasinal turbidites



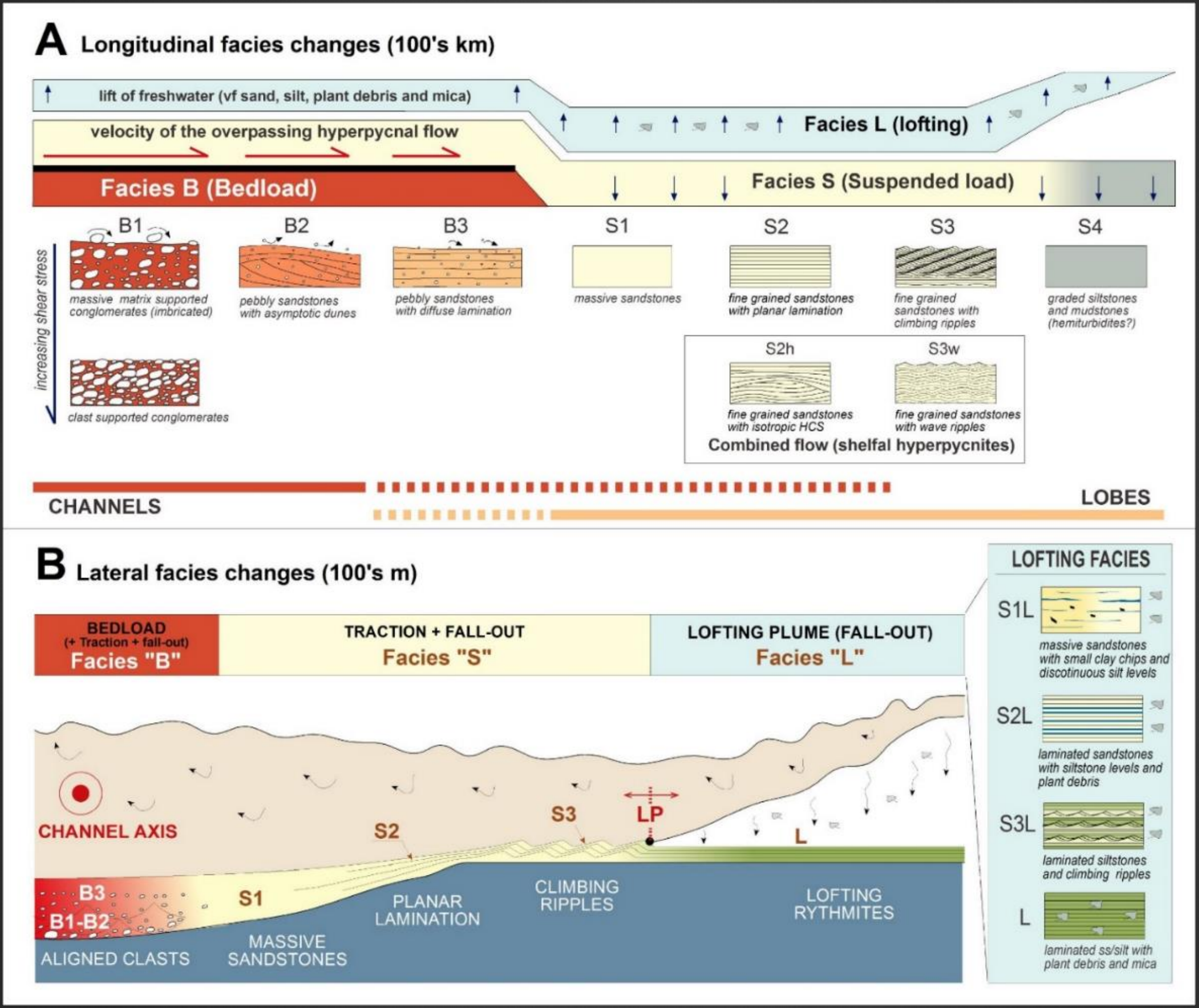


perspective view showing the Florida Escarpment cut by gullies (intrabasinal turbidites) and a meandering submarine channel (extrabasinal turbidites) related to the Mississippi delta, formed at water depths of more than 3,000 meters. Image modified from the USGS webpage, http://pubs.usgs.gov/fs/seafloor-images/

Extrabasinal turbidity currents



A: Diagram showing the sinking of a hyperpycnal flow. Redrawn after Knapp, 1943. B: Main characteristics of long-lived hyperpycnal flows and their typical deposits (From Zavala et al., 2011).



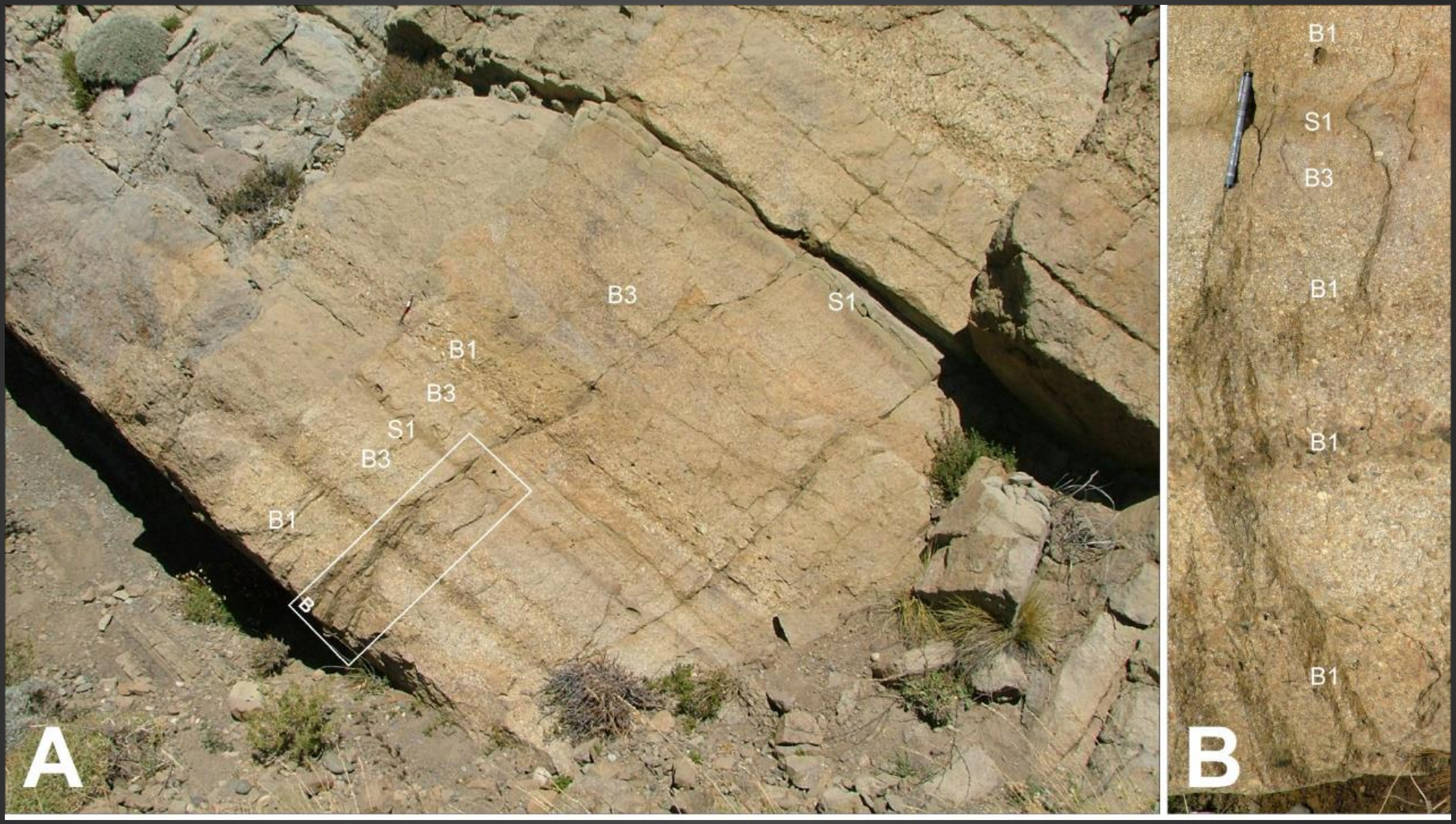
Genetic facies tract for the analysis of extrabasinal turbidity current deposits with associated bed load.

A) Facies association along the depositional system

B) Lateral facies changes towards the flow margin. Modified after Zavala et al., 2011

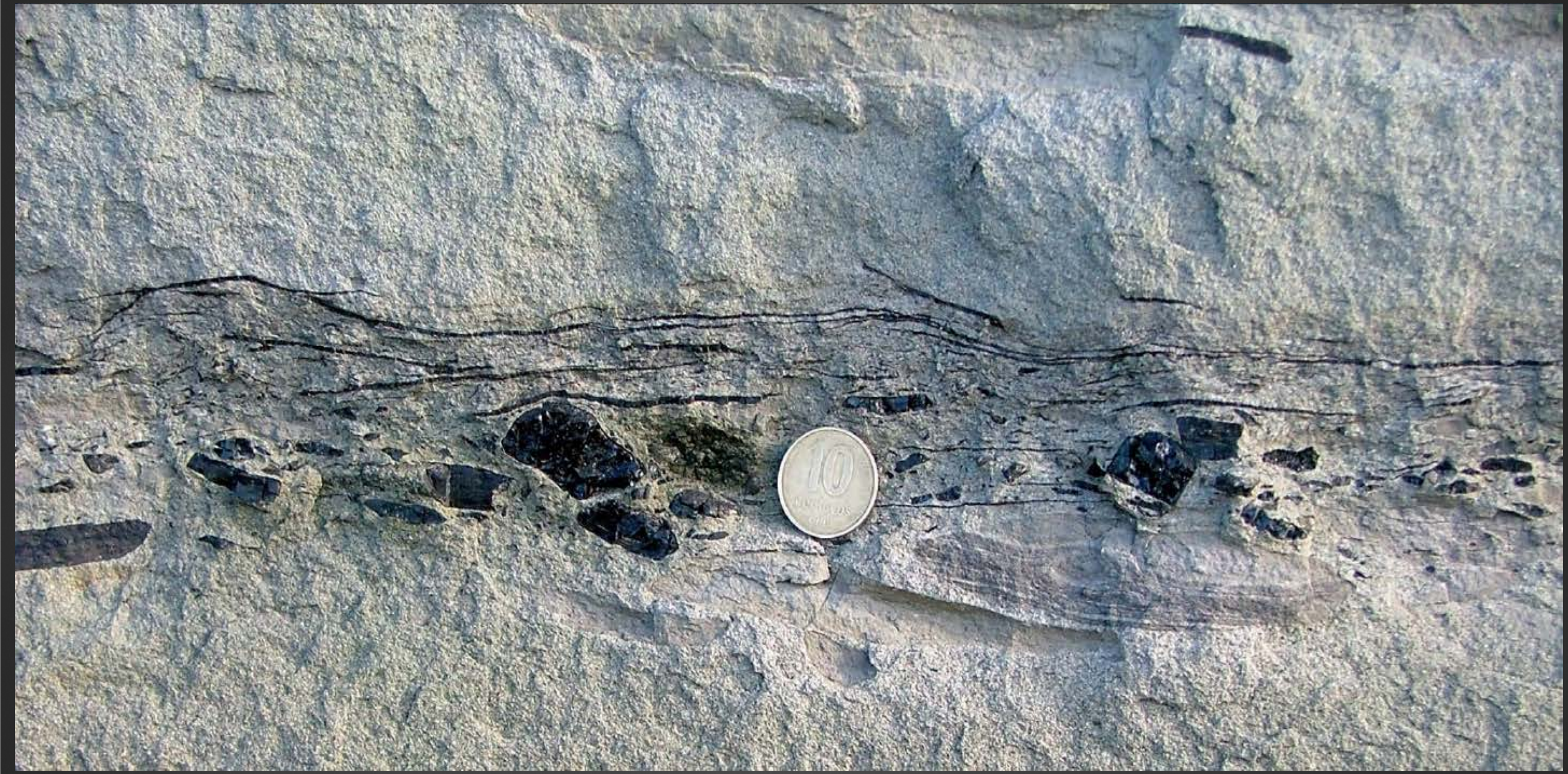
Zavala *et al.* 2011.

Extrabasinal turbidity current deposits



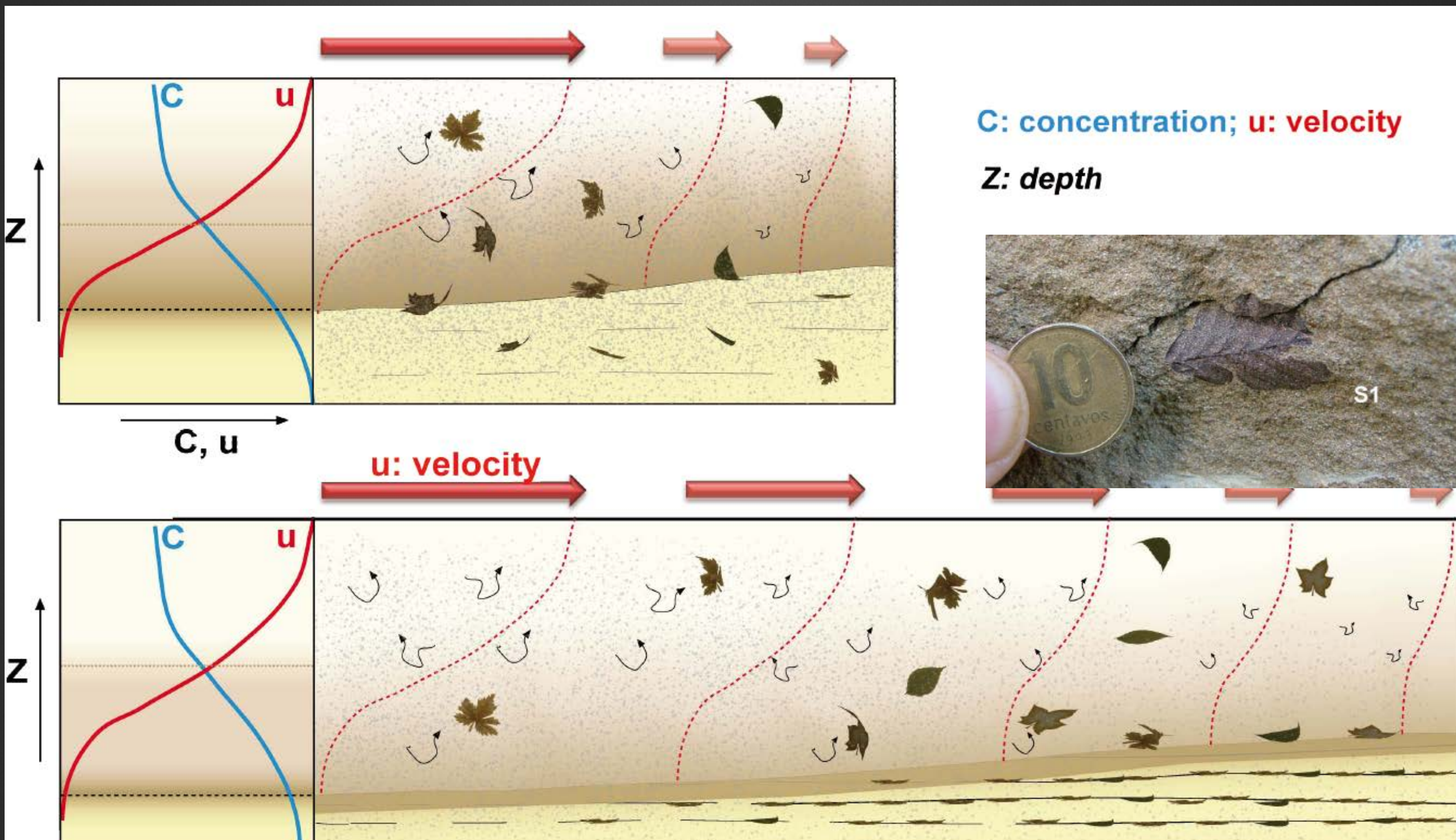
A) Bedload deposits (facies B) accumulated towards the base of a sustained hyperpycnal flow by cyclic variations of flow capacity and competence, forming composite beds. B) Detailed view of the basal segment. Note the gradual changes and recurrence of facies.

Extrabasinal turbidity current deposits



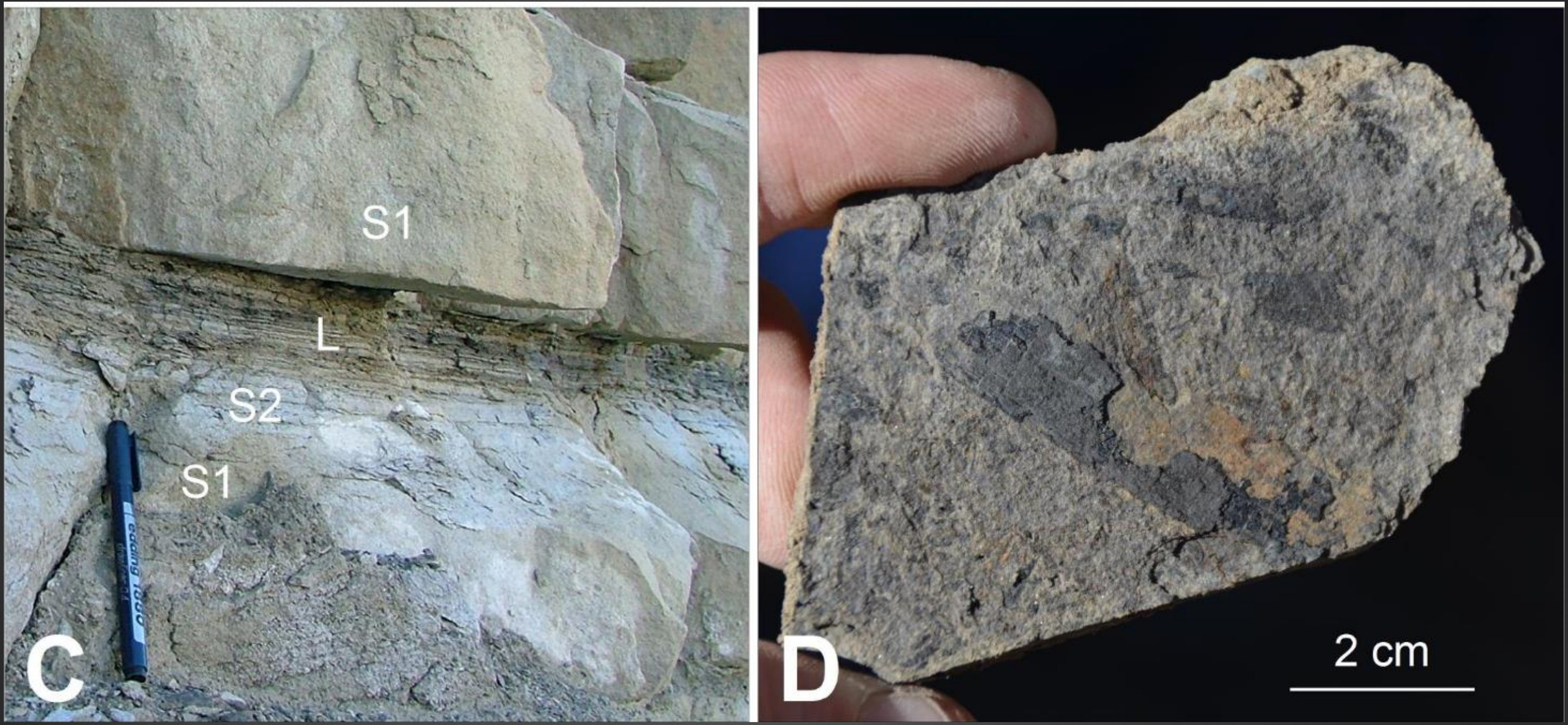
Example of plant debris and charcoal fragments in Lower Miocene deep-water massive fine grained sandstones outcropping at the Cabo Ladrillero locality, Austral Basin, Argentina.

Extrabasinal turbidity currents



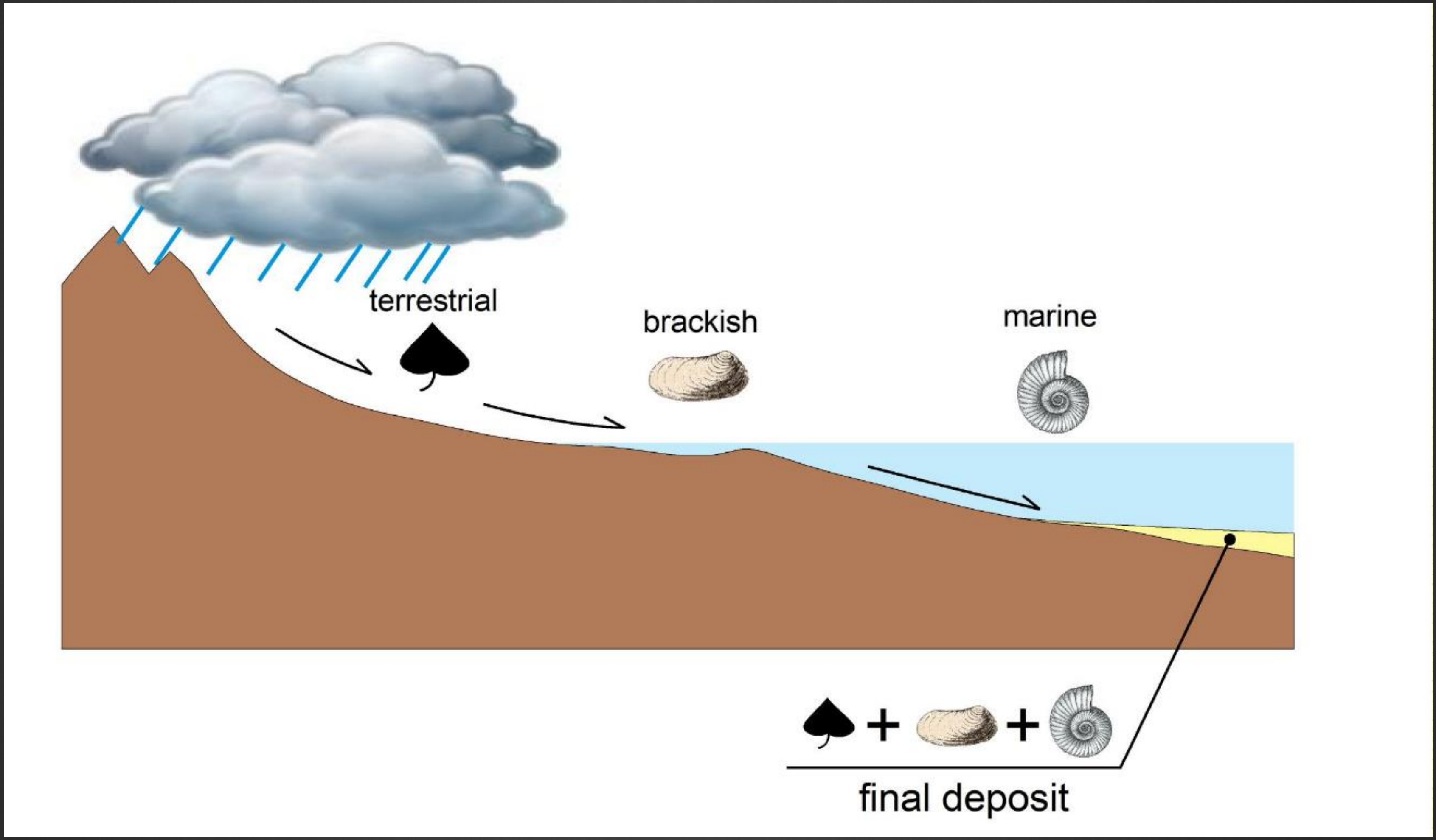
Plant materials transported within the hyperpycnal flow are trapped in the basal deposit

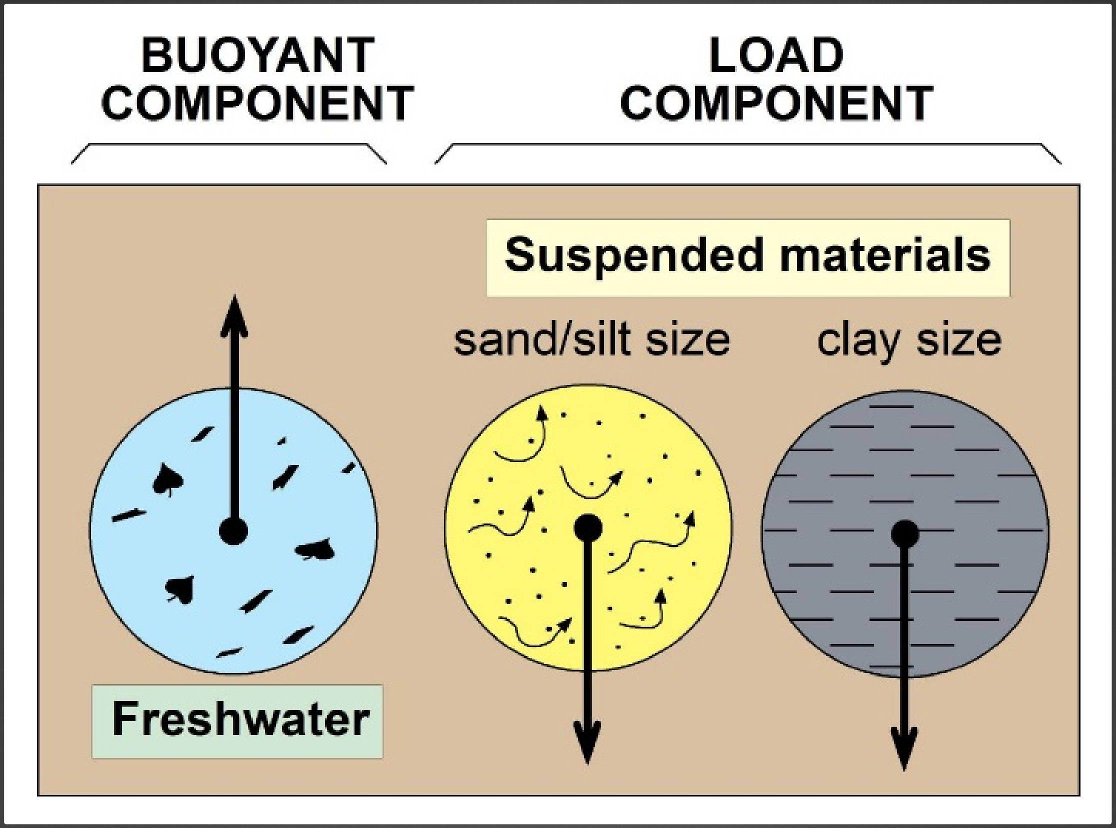
Extrabasinal turbidity current deposits



C) Massive sandstones (facies S1) followed by laminated sandstones (facies S2) and lofting rhythmites (facies L), with abundant plant remains. Los Molles Formation, Jurassic, Neuquén Basin. D) Detail of vegetal remains (plant view) in lofting rhythmites. Huncal Member (Vaca Muerta Formation), Lower Cretaceous, Neuquén Basin.

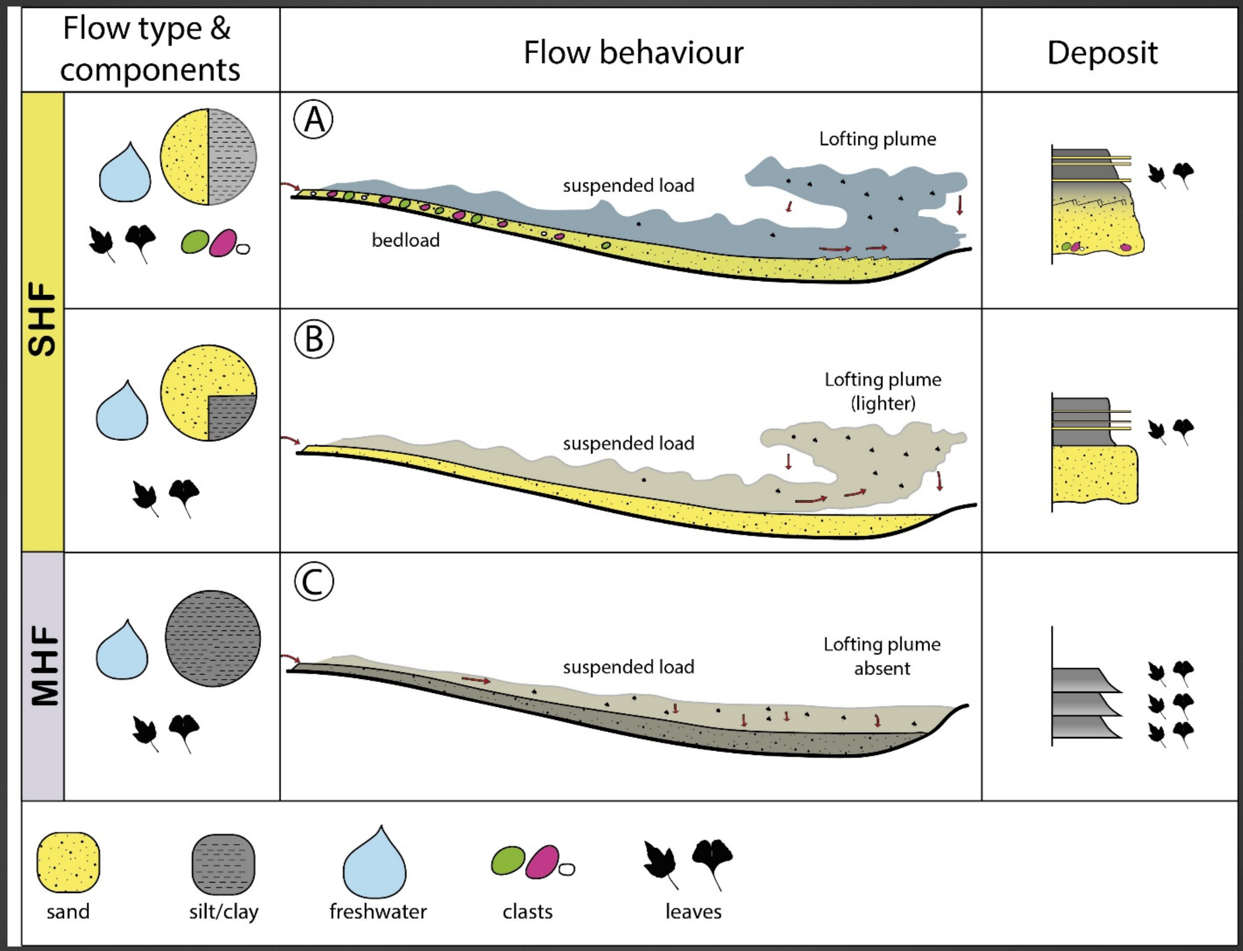
Extrabasinal turbidity currents and body fossils



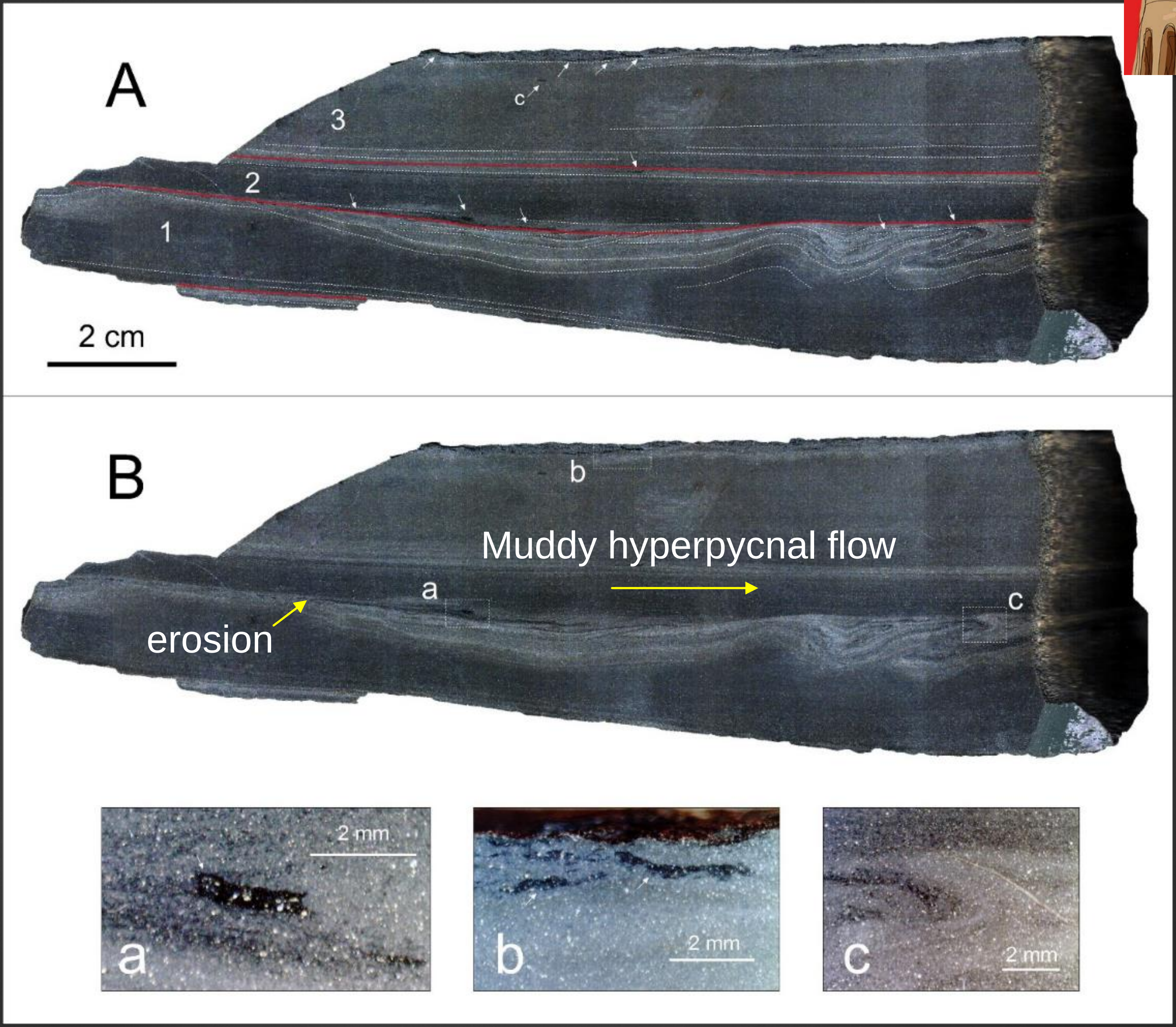


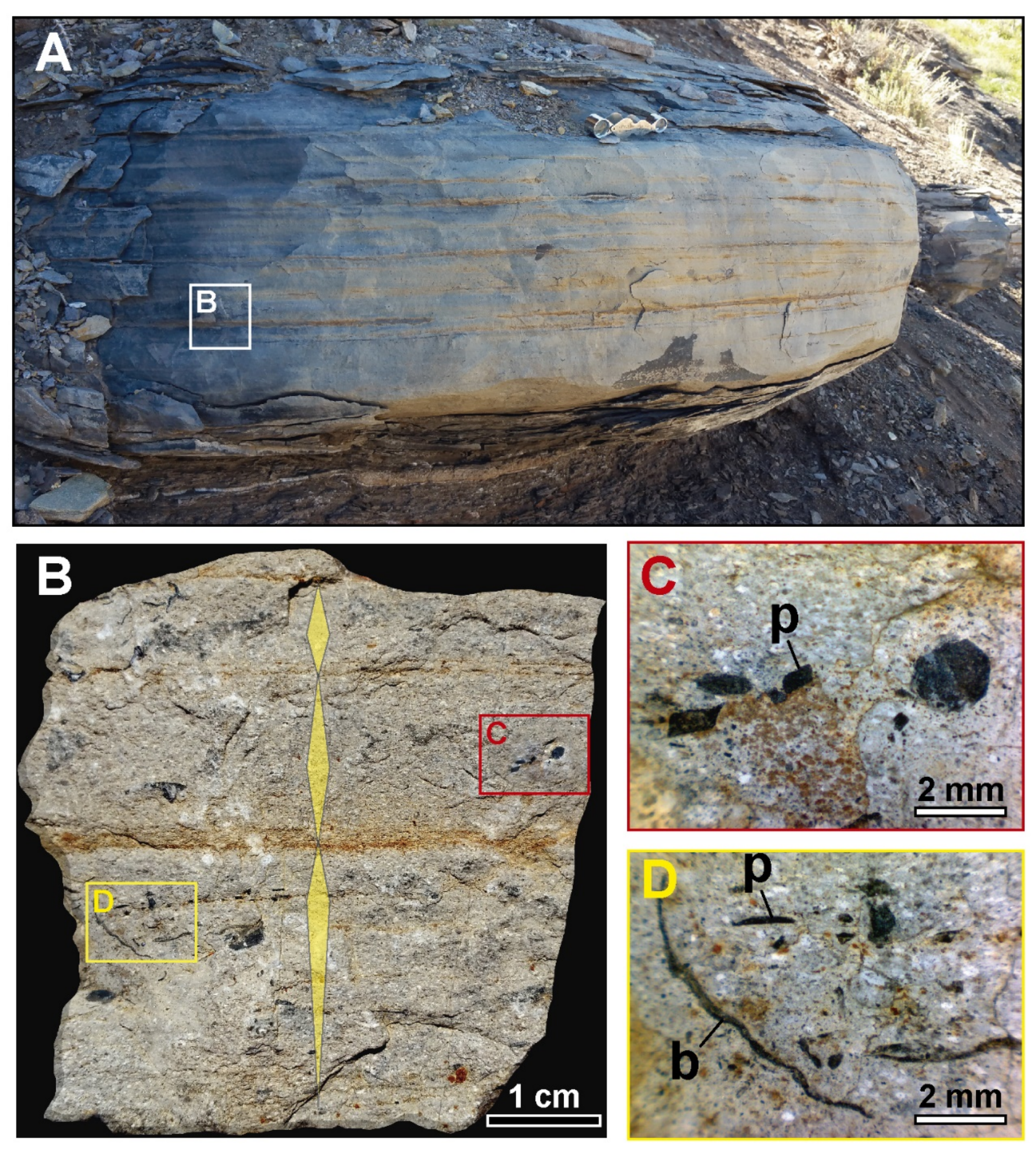
Main components of a hyperpycnal flow. The excess of density is provided by the heavier materials transported in turbulent suspension. After Zavala et al., 2011.

Sandy and muddy hyperpycnal flows



Composition of hyperpycnal flows and their related deposits. A and B) Sandy hyperpycnal flow (SHF) with (A) or without (B) associated bedload. C) Muddy hyperpycnal flow (MHF). Note that density reversal (lofting) doesn't occur in muddy hyperpycnal flows.


A
3
2
1
c
2 cm
B
b
a
c
Muddy hyperpycnal flow
erosion
a
2 mm
b
2 mm
c
2 mm



Field example of deposits related to muddy hyperpycnal flows (facies S4). The analysis is facilitated on concretions because early cementation "freezes" the original deposit and preserve these sediments from compaction

A) Laterally extended centimeter-scale muddy (silt-clay) beds on a large concretion.

B) Detail of A showing coarsening-fining upward cycles with abundant intrabasinal and extrabasinal elements.

C, D) Microphotographs of B, showing a mixture of plant remains (p, extrabasinal) and small mollusks (b, intrabasinal). Upper Jurassic-Lower Cretaceous Vaca Muerta Formation, Neuquén Basin, Argentina.

Conclusions and perspectives

- ✓ Intrabasinal and extrabasinal turbidity currents are essential elements that allow to justify the transfer of huge volumes of clastic sediments into shelf and inner basin by the periodic gravitatonal collapse of coastal/slope deposits or the direct transfer from rivers in flood respectively.

- ✓ **Intrabasinal turbidity currents** are an efficient mechanism to restore the equilibrium profile in sedimentary basins characterized by a marked misbalance in the sediment supply between coastal and inner basin areas.

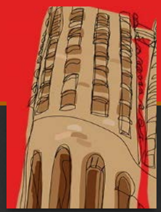
- ✓ Triggering of intrabasinal turbidity currents are mostly related to gravity instability induced by tectonic activity (earthquakes) or the periodic collapse of sediments accumulated close to the shelf margin (e.g. shelf margin deltas) mainly during lowstands.

Conclusions and perspectives

- ✓ **Extrabasinal turbidity currents** allow the direct transfer from the continent of freshwater, sediments and organic matter (mainly plant remains) to the shelf and inner basin.

- ✓ The volume of plant remains could be very important (Huc et al., 2001; Saller et al., 2006), constituting important source rocks for oil and gas.

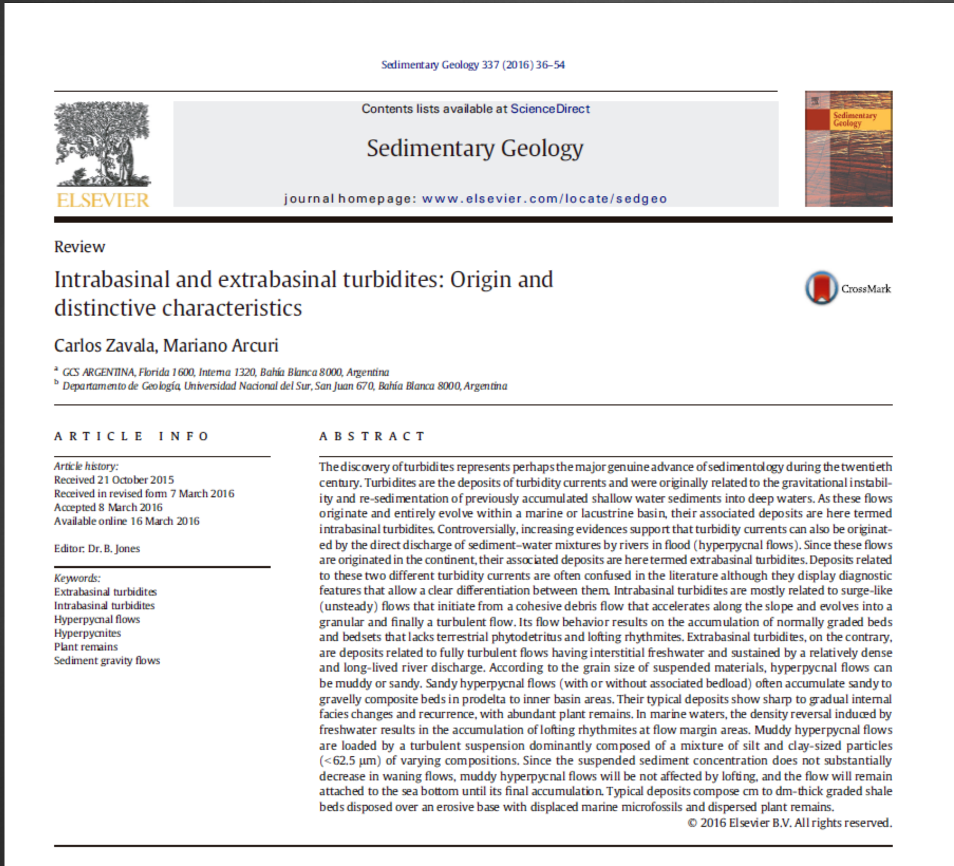
- ✓ Depending on the volume of the related fluvial discharge, the grain-size of the turbulent suspension, and the existence (or not) of associated bedload, the resulting deposits (hyperpycnites) could range from thick and internally complex beds of sandstones and conglomerates to graded shale levels with plant remain and displaced marine and terrestrial microfossils.



Conclusions and perspectives

- ✓ The final thickness and extension of their deposits with depend of the duration of the related fluvial discharge and the basin topography.
- ✓ Since the origin of extrabasinal turbidity currents is mostly related to climatic factors (heavy rainfalls), its occurrence will be independent respect to the position of sea level.

Thanks for your attention!



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Review

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ABSTRACT

The discovery of turbidites represents perhaps the major genuine advance of sedimentology during the twentieth century. Turbidites are the deposits of turbidity currents and were originally related to the gravitational instability and re-sedimentation of previously accumulated shallow water sediments into deep waters. As these flows originate and entirely evolve within a marine or lacustrine basin, their associated deposits are here termed intrabasinal turbidites. Controversially, increasing evidences support that turbidity currents can also be originated by the direct discharge of sediment–water mixtures by rivers in flood (hyperpycnal flows). Since these flows are originated in the continent, their associated deposits are here termed extrabasinal turbidites. Deposits related to these two different turbidity currents are often confused in the literature although they display diagnostic features that allow a clear differentiation between them. Intrabasinal turbidites are mostly related to surge-like (unsteady) flows that initiate from a cohesive debris flow that accelerates along the slope and evolves into a granular and finally a turbulent flow. Its flow behavior results on the accumulation of normally graded beds and bedsets that lacks terrestrial phytodetritus and lofting rhythmites. Extrabasinal turbidites, on the contrary, are deposits related to fully turbulent flows having interstitial freshwater and sustained by a relatively dense and long-lived river discharge. According to the grain size of suspended materials, hyperpycnal flows can be muddy or sandy. Sandy hyperpycnal flows (with or without associated bedload) often accumulate sandy to gravelly composite beds in prodelta to inner basin areas. Their typical deposits show sharp to gradual internal facies changes and recurrence, with abundant plant remains. In marine waters, the density reversal induced by freshwater results in the accumulation of lofting rhythmites at flow margin areas. Muddy hyperpycnal flows are loaded by a turbulent suspension dominantly composed of a mixture of silt and clay-sized particles ($<62.5\ \mu m$) of varying compositions. Since the suspended sediment concentration does not substantially decrease in waning flows, muddy hyperpycnal flows will be not affected by lofting, and the flow will remain attached to the sea bottom until its final accumulation. Typical deposits compose cm to dm-thick graded shale beds disposed over an erosive base with displaced marine microfossils and dispersed plant remains.

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