

## **Variability of Incised Valleys and Estuaries Along French Coasts: An Analog to Oil Reservoirs Where Topography Influence Preservation Potential?**

E. Chaumillon

La Rochelle University, UMR CNRS 6250 LIENSs, 2 rue Olympe de Gouges, 17000 La Rochelle, France  
eric.chaumillon@unv-lr.fr

B. Tessier

Université de Caen, UMR CNRS 6143, 2-4 rue des Tilleuls, 14000 Caen, France  
And J.-Y. Reynaud  
Muséum national d'Histoire naturelle, UMR 7193, ISTEP, F-75005, Paris, France

### **Introduction**

The stratigraphy of incised valleys and estuaries sediment infill is the topic of many studies and international publications since the beginning of the 1990's [Dalrymple, 2006]. The growing interest for incised valleys and estuaries partly arises from the fact that they represent key objects for sequence stratigraphy analyses at the land-sea transition. This is particularly important in the perspective that numerous oil reservoirs, including those of the Mc Murray formation, are made up of sand-dominated bodies forming part of incised valley fills.

Studies on present-day French estuaries, coastal marshes and adjacent beaches have even progressed significantly for ten years. A large amount of new data actually opened new ways linking time scales of physical processes to estuarine sediment body construction in areas of well-known hydrodynamic controls. In order to have an overview of these works, we published a special issue of the BSGF [Chaumillon et al., 2010] with a selection of case studies focused exclusively on the recent progress made on modern systems (Fig. 1). The coasts and inner shelves of France could be qualified in general as sediment-starved systems. This characteristic constitutes the common feature of all the study sites and implies that in most of the cases there is major control of antecedent topography on sediment-fill of incised-valleys and estuaries.

### **Theory and/or Method**

Sea-level change is the primary factor controlling the infilling of the modern French incised-valleys presented in this synthesis. Most of the valley fills are simple (as opposed to compound), in that most of the deposit corresponds to the Holocene sequence. Such a pattern can be explained by a relatively low sediment supply combined with low subsidence and strong regressive and transgressive erosion within the valleys. A major result arising from this synthesis is the very high variability of incised-valley morphologies and sediment-fills which is not shown by the single model for incised valley-fill [Zaitlin et al, 1994]. This variability cannot be explained by sea level variations during the Holocene which were relatively similar along the French coasts. Thus the observed variability in valley-fills is explained by other controlling factors including hydrodynamics (waves, tidal currents, and fluvial input), sediment supply (basically marine and fluvial including small and large rivers), geomorphology (rocky versus depositional coasts), climate and human activities.

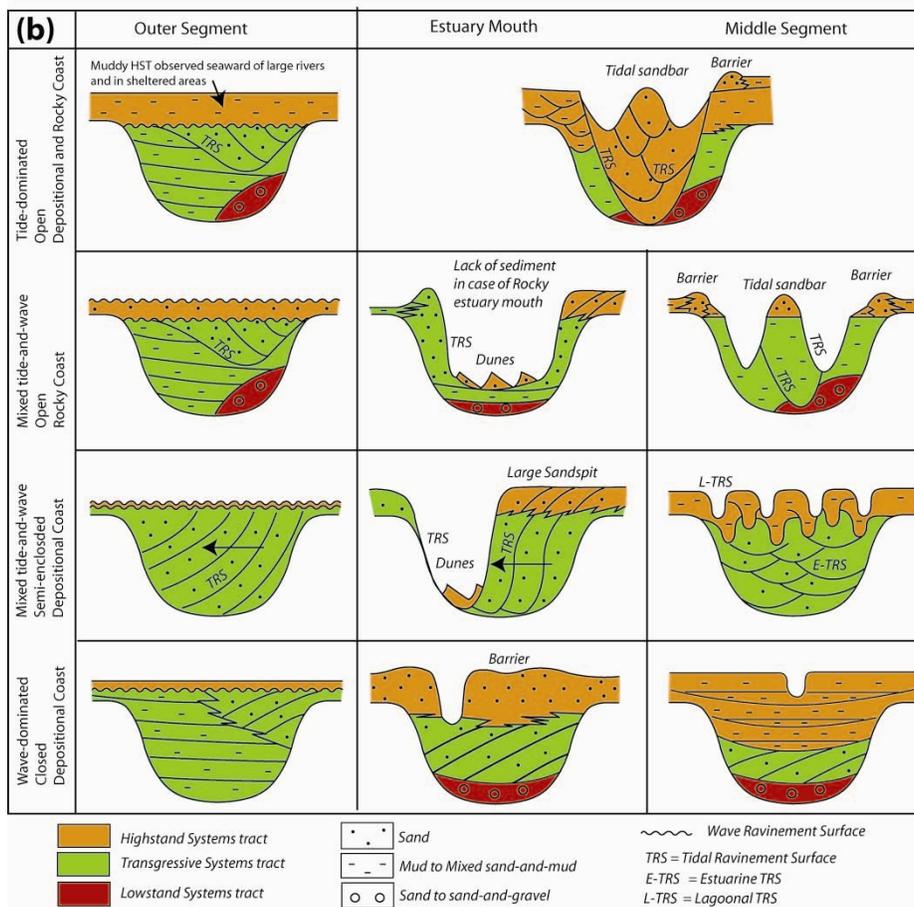
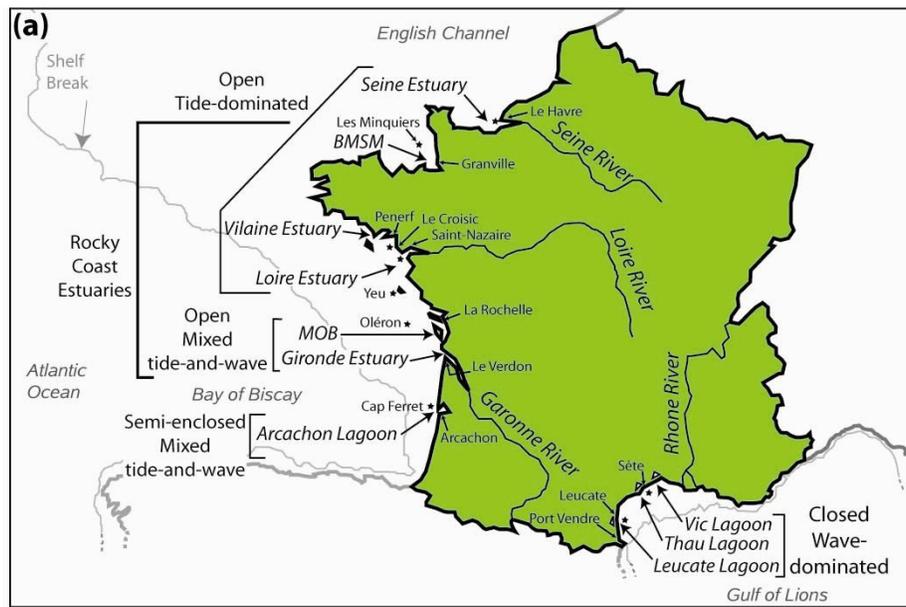


Figure 1: (a) Location map of the studied incised valleys, estuaries and lagoons presented in this study. The classification refers to present-day hydrodynamic (waves and tide) and morphologic (open, semi-enclosed and barred) parameters. (b) Schematic strike-line cross sections showing the variability of French valley fills related to their energetic and morphologic classification.

The observed variations allow defining valley-fill categories that match the classification based on the energy/morphology of the related present-day estuaries (Fig. 1). Three valley-fill categories are distinguished: tide-dominated, mixed tide-and-wave and wave-dominated. Then the first-order controlling factor explaining the observed variations in valley fills is hydrodynamics. Within the outer segments of the valley fills, the HST to TST ratio globally increases from the wave-dominated to the tide-dominated category. This is explained by a deeper wave base in shorefaces belonging to wave-dominated environments. The fluvial sediment supply is another controlling factor for the development of the HST as evidenced by mud field development offshore estuaries connected with large rivers. Those mud fields are the result of expulsion of suspended matter from the estuary during flood events. The TST consists of the bulk of the valley fill in the outer segments of each category. Within the middle segments of the valley fills, the HST to TST ratio is larger in both the tide-dominated and wave-dominated categories. In the case of the tide-dominated category, this is explained by a deep tidal ravinment surface and related large tidal accommodation space that allowed the development of thick tidal sand bodies within the HST. In the case of the wave-dominated category, the thick HST corresponds to the aggradational lagoon fill preserved thanks to the development of a barrier when the sea level rise decreases around 6500 years BP. In the mixed tide-and-wave category, the HST corresponds to the bay-head delta and to progradational intertidal flats and marshes. In cases of incised valleys connected to small rivers, the bay-head delta is reduced or absent. The second-order controlling factor explaining the observed variations in valley fills is the antecedent morphology of the bedrock. Bedrock topography can directly control the local hydrodynamics as evidenced from wave sheltering by offshore topographic sills or tidal scouring and tidal amplification related to flow constriction between bedrock highs. Bedrock topography also controls sediment supply. Valley location with respect to littoral drift seems to be a critical parameter, as the downdrift valley is starved of sand because sand is trapped by the updrift valley. In other cases submerged highs may trigger or delay the development of sandy barriers. The bedrock topography also controls the accommodation space and preservation potential. Preservation is enhanced in secondary valleys which are perpendicular to the main valley where tidal scour occurs. In the case of shallow depth of bedrock incision, the control on accommodation space and preservation potential is important. In examples where an irregular, rocky morphology of the basement occurs not only below but rather above the sea-level highstand line, the bedrock control on the sedimentary fill lasts throughout the entire depositional sequence. Those examples named “rocky coast estuary” by Chaumillon and Weber [2006] can be considered as an intermediate case between depositional coast estuaries and typical rias developed on high relief coast. Another major result is the demonstration of the control of high frequency climate events on the HST of incised valley fills. Barrier destruction and successive tidal incisions are interpreted as the record of periods of enhanced storminess occurring at a millennial periodicity. Such surge periods could be responsible for raised terraces, beaches and overbarrier deposits that were formerly interpreted as short-termed transgressive pulses of the Holocene.

A last result which is specific of modern estuaries is the role of human activities. For the last millenaires or centuries, humans have caused a dramatic increase in erosion of the fluvial catchment areas through deforestation, agriculture, urbanization and damming. In some cases, an increase in mud content is observed in the upper HST and is interpreted as an increase in riverborne sediment supply recording soil erosion in response to extensive deforestation.

## Conclusions

Such diversity showed by French incised-valleys highlights the high variability of incised valley-fills and contributes to complement the single facies model of Zaitlin *et al.* [1994]. The opportunity to compare such different incised valley-fills deposited in the same context of sea level variations provide new insights for the relative importance of hydrodynamics, antecedent morphology and climate controlling these

sedimentary systems. The key-role of antecedent morphology on hydrodynamics, sediment supply, accommodation space and preservation potential in many modern French incised-valleys suggest they could be used as analogs for oil reservoirs located in ancient incised-valleys where paleotopography had a great influence on paleodrainage and preservation of successions like within the oil sands McMurray formation [Hein & Cotterill, 2006].

## Acknowledgements

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