

## RÍAS AND TIDAL-SEA ESTUARIES

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### Summary

Coastal inlets such as estuaries, rías and bays occupy areas which are partially exposed to wave action and the hydrodynamic processes generated by tidal currents and fluvial discharges. These processes are often quite complex, and regulate many of the morphological and sedimentological characteristics occurring in this type of environment.

In aerial view, rías and estuaries are characterised by a funnel-shaped geometry and deep entrances, with a considerable reduction on both dimensions upstream. From a physiographical viewpoint, both types are classified as drowned river valleys as they were formed by sea flooding of Pleistocene-Holocene river valleys during the last transgression.

This chapter is a review of the main processes and attributes in rías and tidal-sea estuaries, initially focusing on the basic physical processes, morphology and sedimentology, with some examples highlighting the differences between both types which, historically, were considered as one. To document the Late Quaternary history of the Rías Baixas on the north-west Atlantic coast of Spain, a brief description of the sedimentary infilling is presented. It is also intended to form a discussion of individual cases, and to the more specific characteristics given in other works in this volume, that were only briefly mentioned in the present article.

## 1. Introduction

The term “ría” originally dates back to the Middle Ages, as Méndez states in a recent publication. It is found in the 1495 edition of a Spanish-Latin vocabulary by Elio A. de Nebrija with the meaning of “river port, ostium fluminis”. The same definition appears in diverse cartographic documents covering the old Kingdom of Galicia (NW Iberian Peninsula) from the sixteenth century. In 1780, the Royal Academy of the Spanish Language generalised its use to refer to a geographical area with a characteristic topography or morphology, defined as “the part of the river at the sea outlet”. In the anonymous nineteenth century Dictionary of Spanish Geographical Terms, “ría” is described as “the lower part of a river, and near its outlet into the sea, to where the tide reaches and where fresh and salt water mix”.

The term was introduced into the literature of Earth Sciences by the German geomorphologist Von Richthofen in 1886. He used the term for funnel-shaped or wedge shaped drowned valleys on coastal areas lying transverse to the regional structural direction of the land; in contrast to the Dalmatian coast of former Yugoslavia, which parallels the structural directions of the land. He took the Galician name used locally for the deep inlets that are so well developed in the region.

Once the term “ría” was introduced into the scientific literature, adapted from Von Richthofen’s initial system, a relative, albeit still limited, knowledge of the same was achieved by comparing the ample literature with the numerous works on many estuaries found worldwide. Some of the most outstanding pioneering works include those by Schurtz, Scheu and Torre Enciso in the first half of the twentieth century; these focused on the origin of the term in geographical papers and interpretations of the existing cartography, as noted in Carlé on geomorphology and tectonics. Nonn analysed topographic forms and established a classification for the rías on the Galician coastline, based on their most significant morphological features. More recent works such as those by Pannekoek in 1966 attributed rías to Hercynian faults reactivated during the Tertiary.

The term “estuary” is derived from the Latin “aestus”, meaning “of the tide”. This means that the term is applied to any coastal environment where the tide is particularly important. A wide range of definitions exists, depending on the different disciplines concerned with the study of estuaries. Many are contradictory, due to the different types of knowledge in the hands of the researchers, or due to the specific characteristics of the estuary being studied.

In the latter half of the nineteenth century, the terms “ría” and “estuary” were considered synonyms and had the meaning which each individual scientist cared to give it, depending on the characteristics to be highlighted. Both cases were considered only as a part of the river mouth and the definitions given were variations which attempt to detail the definition given by Cameron and Pritchard (1967), adapted from a previous version given in 1952. This initial definition established that an estuary “involves a water body partially enclosed in a coastal area, with free connection to the sea and within which it is possible to measure the water diluted by the freshwater deriving from land drainage”. It was not until the early 1950s when interest was aroused in estuaries,

not only in terms of geomorphology, but increasingly in sedimentology, and their characteristic sediment transport.

From a geological viewpoint, it is no easy task to clarify many of the questions regarding estuaries. The systems proposed by Pritchard (1967) or Fairbridge (1980) establish solid bases for a more in-depth understanding of these coastal environments. Pritchard considers large scale processes, such as tectonics and eustatics, presenting different basic physiographic types of estuaries, establishing a physical limit demarked by the tidal influence. Fairbridge, in contrast, considers a dynamic system based on the affecting changes over a short period of time; seasonal changes caused by fluvial discharges, and at the same time as demarking chemical type limits in terms of the degree of dilution or concentration of salinity (see Figure 1).

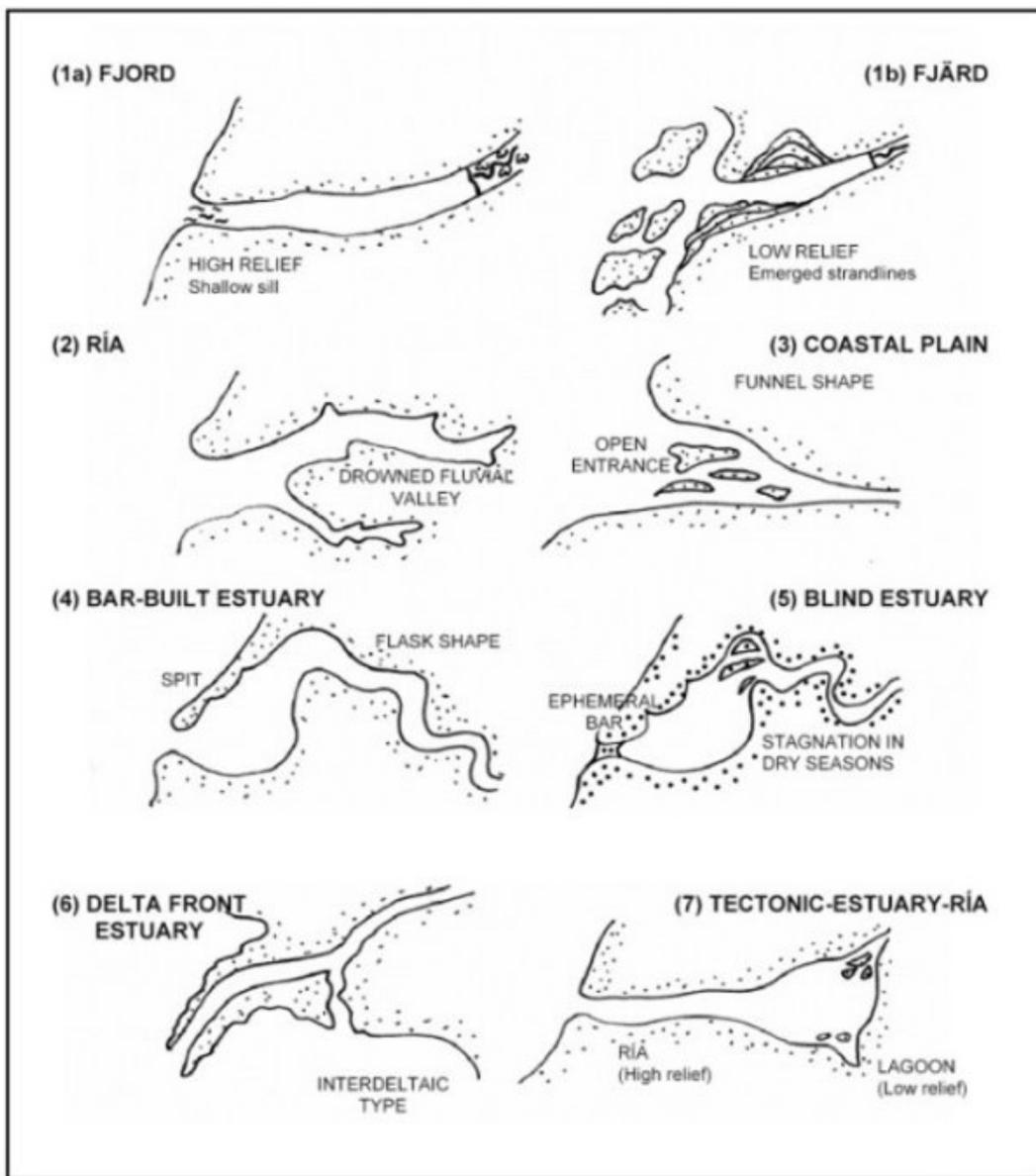


Figure 1. Physiographic types of estuaries based on the dynamic system over a short period of time (modified from Fairbridge, 1980)

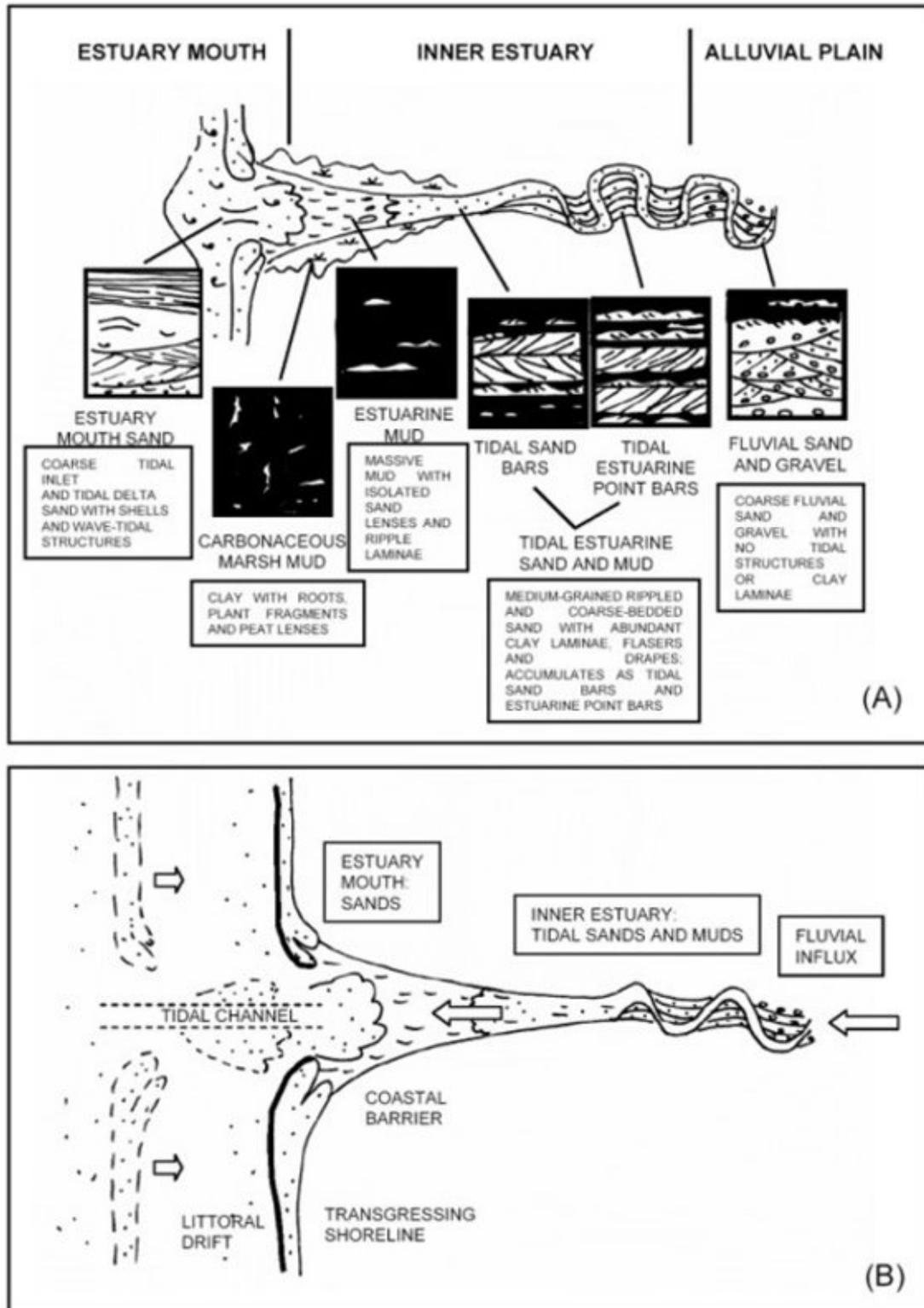


Figure 2. Morphological characteristics and facies patterns on the Gironde Estuary, showing different infilling stages in the basin (modified from Allen and Posamentier, 1994).

From the geological standpoint, Schubel in 1972 indicates that tectonic estuaries correspond to those that fill basins formed by faulting or other diastrophic movements. More recently, Hume and Herdendorf, in 1988, gave a classification based on the primary mechanism that shaped the basin prior to the possible modifications produced by Holocene processes.

More recently Perillo (1995) gave a new morphogenetic classification of estuaries following the criteria given by Shepard in 1973 in his classification of shorelines. From the sedimentological viewpoint, the studies conducted by different researchers on the U.S. east coast and European Atlantic coasts, have shown that estuaries affected by high energy waves and tides exhibit characteristic morphological and facies patterns, which highlight the various refilling stages occurring in the basin, both in the axial and lateral direction of an estuary (see Figure 2).

Pritchard (1967) clearly defined the oceanographer's viewpoint when he defined an estuary as a semi-enclosed water body which has free connection with the open sea and within which sea water is measurably diluted by fresh water. The landward limit, according to the definition, is where the salinity falls below 0.1‰ (normal sea water has a salinity of 36‰).

While this type of definition is highly valid in biological studies, this is not the case for studies of a geological nature, as it includes in some cases, and excludes others, areas which, due to their evolution, have formed as part of estuarine systems. Pritchard divided estuaries into three types, essentially based on the method of mixing of fresh and marine waters (Figure 3): A) Salt wedge estuary, B) Partially mixed estuary, and C) Vertically homogeneous estuary.

There is a fourth type called a negative estuary, but this has not received as much attention as the others. Hayes (1975) classified estuaries into three main types based on their tidal range: macrotidal (>4 m tidal range), mesotidal (2 to 4 m) and microtidal (<2m). Dalrymple *et al.* (1992) consider that for an area to qualify for the term 'estuary' it must receive sediment from both fluvial and marine sources, as well as containing facies influenced by tides, waves and fluvial processes.

According to this paper, the estuary, as in the case of rías, should be considered to extend from the limits of the coastal facies near its mouth and point of connection with the open sea, to the landward limit of tidal facies at its head. The latter is a point above the zone where sea and fresh water mix, and is merely an area where the sediments are affected by tides.

Based on geomorphological criteria, and not on hydrodynamics and sedimentology, Perillo distinguished between Coastal Plain Estuaries and Rías. According to their coastal relief, the first type occupies low relief coasts mainly produced by sedimentary infilling of the river, whilst rías are former river valleys which have developed into high relief coasts. Most regional studies on rías show hydrodynamic processes similar to those identified in most estuaries. However, considering the sedimentary characteristics and sediment distribution of so-called Rías Baixas, located on the north west coast of

Spain, (Vilas et al., 1995 to 1999), there are differences if we compare them to the facies model established for a mixed energy tide and wave-dominated estuary.

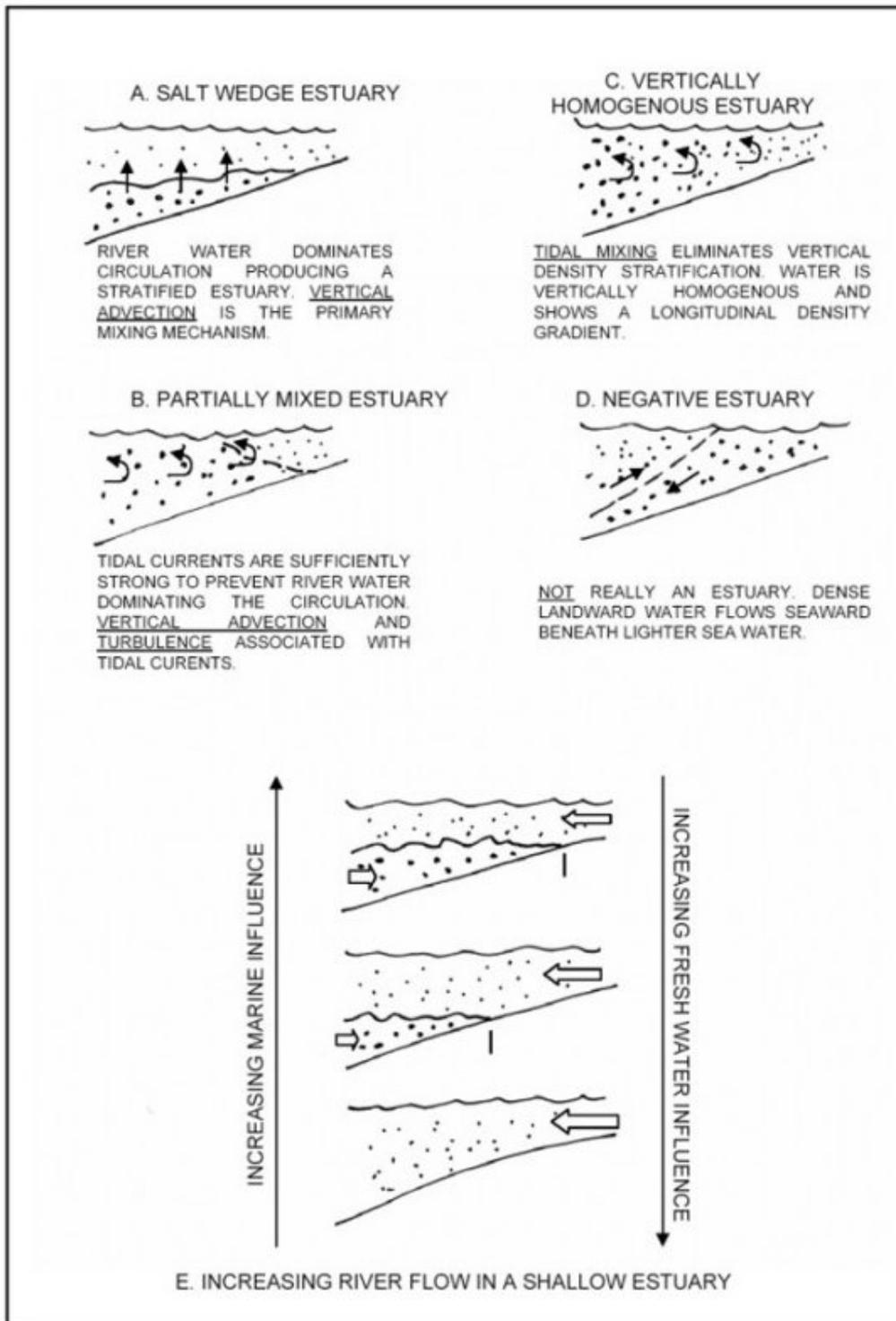


Figure 3. Classification of estuaries based on mixing of fresh and marine waters as proposed by Pritchard (1967), redrawn after Evans (1995).

Following the distribution given by Olausson and Cato of major estuaries in the world related to tidal ranges and climatic zones, the majority of the estuaries developed in former river valleys, such as Coastal Plain estuaries (low relief coasts) and Rías (rocky shores in high relief coasts), are located in subtropical and temperate regions. Those developed in former glacial valleys are given other terms (Fjords and Fjards in Scandinavia, Firth in Scotland, Loch in Ireland), and correspond to cold climate areas. Those known as structural estuaries, however, cannot be related to any climatic or tidal range criteria, but rather to neotectonic processes such as faulting and vulcanism, from the Pleistocene to the present. Based on these considerations, diverse factors are in play (type of coast, lithology, wave-tide energy, river discharge), which control and determine the very nature of a given estuary or ría.

According to Castaing and Guilcher (in Perillo, 1995), the term “ría” should be restricted to the Iberian Peninsula and to some other areas with high relief coasts, such as those in Brittany (France), Devon and Cornwall (UK), Korea, and some parts of the Chinese and Argentine coasts. Summarizing the information given by these authors for the aforementioned regions, all are flooded valleys surrounded by hills, some of them with very shallow entrances filled by small grain size sediments where sand barriers, mud flats and saltmarshes are developed behind them (e.g. in the northern Spanish coast and Brittany). Some others present deeper mouths ranging from 30 to 50 m, progressively decreasing upstream to fall between 10 and 5 m (north-western Spain, Korea, south-east China, and southern Patagonia (Argentina).

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(The references provided in the text only scrape the surface of the voluminous literature covered in this article. The intention has been to cite the key references which are important to consult for some of the original work on a subject and indicate where further information can be found).

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