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Short Communication

Rias, estuaries and incised valleys: is a ria an estuary?

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Abstract

Today, the term ria is rarely used by sedimentologists or stratigraphers, although it embodies all the characteristics of the so-called incised valleys – a topic of considerable interest since the increased understanding of the three dimensions of transgressive sequences using seismic stratigraphy. When it is used, it is usually referred to as a type of estuary; however, in many cases, only a minor part is influenced by estuarine processes. It is a useful term which should be revived as it encompasses in its entirety all the features and resulting deposits of an incised valley whether it is estuarine or marine.

Keywords: ria; estuary; incised valley; transgression

1. Introduction

Although there has been considerable discussion in the literature about the exact definition of the term estuary, most physical, chemical and biological marine scientists, as well as geologists (stratigraphers and palaeontologists), and geomorphologists are in broad agreement with the hydrographical definitions of Pritchard (1952, 1967):

'An estuary is a semi-enclosed body of water having a free connection with the open sea and containing a measurable amount of sea water.' (Pritchard, 1952)

'An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurable diluted with fresh water derived from land drainage.' (Pritchard, 1967)

However, most geologists and geomorphologists are much less content with the broader, less restricted definition of Ketchum (1951):

'An estuary is a body of water in which river water mixes and measurably dilutes sea water.'

That the mixing takes place in a semi-enclosed water body is an essential part of the geologist's and geomorphologist's concept of an estuary – and this is normally envisaged as a landward extension of the sea as exemplified by such definitions as:

'Inlets of the land that are entered by both rivers and the tides of the sea.' (Lyell, 1830)

'An estuary is a wide mouth of a river, or arm of the sea, where the tide meets the river current or flows and ebbs.' (Stevenson, 1972)

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'An estuary is an indentation in a coast which tidal circulation meets land runoff and generally prevails over the land contribution.' (Gorsline, 1967)

Both geologists and geomorphologists are more concerned about the geometry (hypsography), i.e. the nature of the confining feature of the 'semi-enclosed coastal body of water' than either the physical, chemical and biological marine scientists. Furthermore, another concept, that of the origin of the feature, is one that figures predominantly in most geological and geomorphological texts. Nevertheless, as stressed by Schubel and Pritchard (1990) estuaries cannot be defined solely on morphology and their mode of origin. Both of these are secondary features of a system whose essential characteristic is the mixing and interaction of marine water with incoming river water. This interest in the inclusion of the geometry and the origin in the definition of estuaries is exemplified by one of the latest and widely used definition, which satisfies most of such scientists;

'The seaward portion of a drowned river valley system which receives sediment from both fluvial and marine sources and which contains facies influenced by tide, wave and fluvial processes. The estuary is considered to extend from the inner limit of tidal facies at its head to the outer limit of coastal facies at its mouth.' (Dalrymple et al., 1992)

Hence, it is clear that the latter scientists envisage an elongate feature with limited width which has been produced by a relative rise in sea level and which has been produced by drowning of a previous erosional depression – produced by fluvial erosion. However, a term has long existed for such a feature as a drowned river valley, which has been formed by a relative rise of sea level either because of eustatic changes, tectonic changes or a combination of both. This is the geological term *ria* introduced by von Richthofen (1886). He applied it to rocky coastline where the feature was well developed, particularly on the northwestern coast of Europe as well as elsewhere. He took the name from the rias – an Old Spanish name for these features – of Galicia where they are beautifully developed. In his original discussion, he used the term for features on coastlines, which were transverse to the main geological structure of the adjacent land. However, he realised, and this has become more apparent with increased knowledge, that the Galician coast did not completely satisfy this requirement for most of its length. Torre (1958) divided this ria shoreline into three groups, high, central and low, according to their geological setting, thus stressing the variability of their geological framework (see Vidal-Romani, 1984, for a general review). In an attempt to stay within the original definition, many later writers have suggested that the coast of southwestern Ireland and parts of the coastline of Brittany and other parts of N.W. Europe probably are better type-examples of this feature. Later, Nonn (1966), when writing about the Galician rias, defined a ria as 'une baie plus long que large, dont l'amont est constitué par un vallée ou un system de vallées' where the drowning of the valley could be produced by either tectonic or eustatic changes.

In contrast, others such as Gulliver (1889) suggested the term could be extended to cover 'all types of subaerially carved troughs, including von Richtofen's fjord, dalman, ria and liman types' a view with which few later writers agree. Some workers have suggested that the structural requirement be relaxed and the term should be used generally for the drowned lower part of a river valley (see discussion in Cotton, 1956; Hails, 1982), which is usually rock-bound and would exclude long coastal plain indentations of the sea extending into contemporary alluvial coastal plains such as deltas.

Although the term ria has continued to be employed by geomorphologists, curiously, it is the one rarely used by sedimentologists and stratigraphers when describing the evolution and infill of river valleys drowned by the relative rise of sea level. This is surprising, because the drowned lower courses of rivers and their sedimentary infill have become a subject of great interest to sedimentary geologists, albeit under another name – incised valleys. The interest in these features has increased due to advent of greater stratigraphical control, particularly the use of seismic stratigraphy. It has been realised that they are important features of major stratigraphic breaks, as a result

of large-scale and extensive changes in relative sea level. Furthermore, they are often the sites of valuable petroleum deposits.

2. The case for rias

Lack of use of the term ria is regrettable as the term embraces all the conditions and requirements demanded by stratigraphers (see references in Dalrymple et al., 1994). Indeed, interestingly, the term has been discussed recently and it appears there may be an attempt to revive it. Perillo (1995) in a comprehensive review of the term estuary has suggested that the term ria be used for a so-called primary estuary – 'a former fluvial valley developed in high relief (mountainous of cliffy coast).' He gave the Galician rias as one of his examples without reference to geological structure. Perillo contrasted these features with coastal plain estuaries which 'normally occupy low-relief coasts produced by infilling of river valley,' e.g. such as the Thames, Gironde, etc. In his discussion he was considering rias as a type of estuary. This implies that all rias are estuaries, i.e. they are dominated by estuarine circulation produced by mixing of fresh and salt waters. However, various workers have recently shown the limited extent of estuarine circulation in rias of the Galician coast. In the four Rias Bajas of Galicia the salinity in the mouth is higher than 32 ppt, even during the rainy winters (Prego et al., 2002). Thus the division of the rias into zones (Prego and Fraga, 1992) shows an external oceanic zone and an internal estuarine area (where there is important tidal influence). This condition is exacerbated in some cases (e.g. La Coruña Ria, Varela et al., 1994) by damming of the incoming rivers. It is clear that many rock-bound drowned river valleys, i.e. rias, are not completely dominated by estuarine circulation. The latter is important during the wet season but in the dry season the estuarine circulation does not extend to the external zone of these features (Prego and Fraga, 1992). Although, at such times this North Atlantic coast of Spain is characterised by seasonal upwelling (Prego and Bao, 1997), which strengthens the estuarine circulation, and the salinity remains more than 35 ppt in the entire ria except close to the river mouths. Such intimate intermixing of fresh and salt water is restricted to only their inner parts for much of the year and they are characterised by estuarine circulation only during wet seasons, and then not always, or during periods of exceptional run-off from the land which rarely last for more than one week.

Naturally, during the evolution and the ultimate filling of the features and their preservation in the stratigraphical column, they may have gone through various states from a river valley to an estuary and to, in some cases, a fully marine-dominated embayment with little evidence of land run-off. The exact nature of their evolution would be preserved in their sedimentary infill, which is at present attracting so much attention from geologists (Dalrymple et al., 1994). The relative importance of the various processes at any one time and the nature of the fauna, flora and sedimentary infill will depend upon the speed of the transgression and the ultimate scale of the feature in relation to the size of the drainage basin or, probably more importantly, the size of the water and sediment exchange and may be complicated by additional oceanic processes – such as upwelling as seen in Rias Bajas of Galicia. The greater part of many rias may be essentially inlets of the sea dominated by marine processes which support a marine fauna and flora with little and only occasional influence from the adjacent land mass. Furthermore, they are sites of the accumulation of essentially marine sediments – an important point for the stratigraphers and sedimentologists studying and interpreting ancient deposits. Typically, sand accumulations such as deltas with their associated bars, spits and other features are characteristically found in the inner parts of the ria, except where they have been completely filled or choked with sediment when they can occur near the mouth. Hence a more suitable terminology would be to use ria as an overall term for an incised river valley – which is exactly what it is. These features may be either marine dominated, estuarine dominated or indeed of an intermediate type. In all cases, they were originally rias as defined by von Richthofen with certain reservations due to the structural condition initially laid down

but now universally accepted as being unnecessary.

3. Concluding remarks

The authors do not wish to be pedantic but are making a plea that a useful and old term is one which can still be used with advantage in the understanding of coastal phenomena and ancient stratigraphical sequences. The term is a good overall term, which allows geologists to refer to deposits that have been deposited in such drowned fluvial features. It is interesting to see that, in a recent comprehensive and most useful compilation by Dalrymple et al. (1994) on incised valleys and their fill, the evidence for many of the sediments being truly estuarine is not always conclusive. It is merely their position between underlying fluvial and overlying marine sediments that makes such an interpretation likely. The point is made by some of these authors that all three facies are not always present. Probably many of incised valleys were for most of their history marine-dominated rias, after the original transgression. Of course, during the Holocene rise of sea level, or other rises of sea level in older examples, the estuarine zone would have been driven landwards to the landward head of the ria leaving estuarine and possibly fluvial sediments beneath the subsequent fill of sediment laid down under dominantly marine conditions. Alternatively, if the ria becomes filled with sediment the estuarine zone would have extended seawards and led to a capping of estuarine sediments overlying the marine infill.

The authors do not agree with the views recently expressed by Castaing and Guilcher (1995) that the term ria should be restricted, as a general rule, outside the Iberian Peninsula, to Brittany in France and Devon and Cornwall in the British Isles, Korea, parts of the Chinese and the Argentina coasts. On the contrary, it is a useful term capable of wide application. In conclusion, rias are incised valleys where the estuarine zone can move according to climatic changes. In Galician rias only the inner part can be considered as an estuary from both hydrographic and their resulting sedimentological considerations, with the main estuarine processes being confined to the inner relatively small brackish water zone.

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