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The Vilaine River estuary in the Bay of Biscay: Insight into geomorphologic controls on estuarine sedimentation

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Introduction

Estuarine environments are among of the main critical interfaces at the boundary between land and sea. They receive most of the drainage waters coming from the land through the fluvial network and also intermittently shallow marine waters through tidal and wave processes. These dynamic interrelationships produce an exceptional diversity of environments. The nature and distribution of these environments are described into a few generic models like Zaitlin and Dalrymple (1992) and Ashley and Sheridan (1994) or end members like the Bay of Fundy etc. However the natural diversity is certainly underestimated and many case examples still need to be described and compared to each other.

The Vilaine estuary is located along the French Atlantic coast, in Southern Brittany. It is one of the poorly known French estuaries that was recently strongly impacted by human activity. Fish farming and tourism activities are well installed and a dam was built on the river in 1970 at 8 km from the outlet. Since this construction, fine particles coming from the ocean steadily accumulated in the estuary.

Our goals are here to describe the nature and architecture of the estuarine environments and to interpret their historical evolution through time with regards to forcing mechanisms (hydrodynamic and anthropogenic factors).

Data / Methods

In the following we present results from field observations, aerial photographs analysis, electric tomography and sediment coring. Field studies focused on the coastline and wetlands bordering the estuary. The observations were conducted at a regular time space covering the full range of seasons and tidal regimes. Four series of orthophotographs (IGN National Geographic Institute) and a nautical chart (SHOM) were gathered covering years 1958, 1971, 1993 2000 and 1820 respectively. These aerial photographs were georeferenced and compiled under ArcMap© from the software ArcGis and a synthetic map was constructed for each year by describing the main geomorphological zones like tidal flat, salt marsh, offshore bar etc. To estimate the depth of the bedrock and sediment thicknesses, electrical tomography was performed on salt marsh and tidal flat of the estuary. Direct current electrical profiles were achieved by using a multielectrode data acquisition system connected to cables with 64 electrode plugs (Nicollin et al, 2006). 5 m electrode spacing provides a total layout of 320 m long and the depth of investigation reach 20m. Data integrated in pseudo sections of apparent resistivity provide a preliminary electrical image of sediment thicknesses and geometries. Tomographic interpretations are groundtruthed by series of sediment cores. The cores were extracted with a Russian corer that consists of a one m-long, semi-cylindrical tube of and several one m-long, drill pipes.

Results

The Vilaine estuary drains a large catchment area of about 10 400 km^2 that represents one third of the Armorican massif. It receives 600 to 1000 mm of rain per year under a largely oceanic climate. The river flow is highly variable with only 2 m^3/s in the 1989 slack waters, 1500 m^3/s in the 1995 flood event and 80 m^3/s in average. The river carries a sediment load of 0.1 million tons per year. It is a mixed suspended and bed load meandering river on most of its course flowing on a Palaeozoic magmatic and metamorphic hard rock basement but 8 km from the dam sediment accumulate onto the river bed partially filling the estuary. The estuary is affected by macrotidal, semi-diurnal, tidal regime with tidal currents reaching a maximum velocity of 2 knots in high spring tides. The most significant swells come from the NW.

Description

The Vilaine estuary sediments filled a 20m-deep, fault bounded asymmetric valley that can be divided into 6 main domains.

Zone 1 (Vilaine channel) is comprised of the main channel of the Vilaine River. It exhibits a meandering stream that straightens progressively in a seaward direction and towards the 2km-wide outlet. The channel is between 4 and 6m deep. The draught is being maintained by dredging to ensure summer leasure and work boat traffic. This channel is bordered by important mussel farming.

Zone 2 (Banc du Strado) is a muddy tidal flat made up of silty muds over 20m-thick. Mud deposition on the tidal flat occurs according to seasonal rhythms.

Zone 3 (Pointe du Halguen) is a rocky area bypassed by sediment provided by the northward longshore drift;

Zone 4 (Dunes de Ménard) is a lowland area infilled during the last centuries by marsh silty-mud preserved at the back of a ridge formed by compound storm washover fans lying on mixflat deposits. The ridge forms a narrow band of shelly sand or pebbles along the coastline while the mix tidal flat is made up of alternating layers of silty-mud, sand and pebbles. The mixflat deposits are estimated over 20m-thick.

Zone 5 (Betahon) is comprised of salt mashes preserved at the back of a barrier beach and cross cut by a small permanent river stream. The infilling of the back barrier area is over 22 m-thick and made up of a stack of tidal channels and salt marshes alternation.

Zone 6 (Tréhudal, La Grée, Etier du Palud, Vieille Roche, Kerdavid, Bourgerel) encloses a series of small fluvial drainage basins that drained towards the main Vilaine river stream; Most of them are now hardly reached by spring tides feeding local marshes.

Historic evolution

The channel of the Vilaine estuary (zone 1) remains stable through time, maintained by dredging. However bathymetric surveys show that channel depth and width decrease, progressively filled by tidal flats. The zone 2 mud flat is a very active depositional area. Its surface triples in less than 200 years, first in NE-SW and then in a SE-NW directions. Zone 3 barely changed these last two centuries. The coastline is rocky and subjected to slow erosion. The coast constitutes a reflective area for the swell and sediments coming from the south through longshore drift bypass this area to feed the estuary. Sediment provided in zone 4 by longshore drift are transported along the inner estuary, on the mixflats by tidal current and reworked by wave action which build up beach ridges protecting backbarrier salt marshes. Occasionally storm waves build up storm washover fans that can move up about l5m per year with pulses of a few meters at each step. The mix-flat located at the front of beach ridges and storm washovers is installed for more than 200 years. The zone 5 salt marshes are currently covered by spring waters and filled up progressively by the back barrier and small river channels deposits. The zone 6 inner estuary is a very stable depositional environment with mature salt marshes infilling largely inactive catchment areas (zone 6). Since the construction of the Dam Arzal, the edges of these marshes are cut-off by the Vilaine River incision. Rivers are poorly active and sediment is mainly transported by tidal currents during spring tides.

Discussion

A wide variety of sedimentary body is represented along the coastline bordering the Vilaine River estuary. The distribution of these bodies is highly constrained by hydrodynamic forcings. The influence of the swell is reflected by the presence of beach pebbles and shelly-sand into washover fans and barrier along the left edge of the estuary (Zone 4). The influence of tides is also important by creating large tidal flats and salt marshes (Zones 2, 4 and 5). Finally, wind action creates eolian dune deposits (Dunes of Ménard) in the shadow the rocky promontory “La Pointe du Halguen”.

The Vilaine estuary is filled by sediment provided by different sources. The main one is the littoral drift that provides shelly sand and pebbles to the outer part of the estuary. The second one is the mud fraction that feeds the tidal flats provided by ocean and fish farming activities. The continental part represents only 0.1 million ton per year.

The outer part of the estuary clearly shows an asymmetric functioning of the right and left banks that certainly relates to its asymmetrical, fault-bounded original structural shape. From 1820 to 1958, the right bank of the river (zone 2) experienced a lateral growth of 0.5% per year reaching 2% between 1958 and 2000. This growth was only 0.1% and 0.3% per years for the same periods on the left bank (zone 4). This evolution shows that the construction of the dam certainly played a role in this increase in the accretion rate of the mudflats but its influence on the differential growth of the two edges of the rivers is more debatable.

Before the construction of the dam of Arzal, the estuary was fed by both the load of the river and ocean sediment. Since 1970, river sediment load is stored behind the dam when oceanic particulate matters stay in front of it. Salt and fresh waters exchanges are minimal.

Conclusions

The relict landform of the Vilaine estuary valley was certainly a condition for its morphosedimentary evolution. The building of the Dam Arzal surely influenced the hydrosedimentary evolution of Vilaine. The sheltered position at the back of a large embayment, makes also the estuary a relatively well-protected area suitable for sediment preservation.

Further studies are planned to complement the dataset and our understanding of this environment (drill cores, topographic, current velocity and mud aggradation measurements. . .). These new data will complement our knowledge of the Holocene marine transgression along the Atlantic coasts (Proust et al. 2001; Menier et al.,2006).

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