ELSEVIER

Marine Geology 207 (2004) 17–38

MARINE GEOLOGY
INTERNATIONAL JOURNAL OF MARINE GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS

www.elsevier.com/locate/margeo

Architecture and morphology of the outer segment of a mixed tide and wave-dominated-incised valley, revealed by HR seismic reflection profiling: the paleo-Charente River, France

Nicolas Weber[a,b,*], Eric Chaumillon[b], Michel Tesson[c], Thierry Garlan[a]

[a] *Etablissement Principal du Service Hydrographique et Océanographique de la Marine, Cellule Sédimentologie, 13 rue du Chatellier, BP30316 29603 Brest cedex, France*
[b] *Centre Littoral De Géophysique, Université de La Rochelle, Avenue Michel Crépeau 17042 La Rochelle cedex1, France*
[c] *Université de Perpignan, 66860 Perpignan, France*

Received 20 December 2002; received in revised form 12 March 2004; accepted 2 April 2004

Abstract

We present new single-channel high-resolution seismic reflection profiles, ground-truthed by vibrocore data, dedicated to the outer segment of an incised valley connected to the Charente River (French Atlantic coast). The present-day Charente is located about 50 km northward of the well-known Gironde estuary. Those river mouths are comparable in terms of marine hydrodynamic parameters, but strongly differ by their water discharge and catchment area. Seismic data are processed and interpreted to develop a three-dimensional seismic stratigraphic framework for the Charente-incised valley fill. The channel network of the drowned Charente valley is evidenced for the first time, and shows a seaward distributary pattern which is likely influenced by neotectonic control. Incision depth and width of the Charente and Gironde-incised valleys are similar, supporting the idea that correlation between valley width and modern hydrology is poor.

The internal geometry of the Charente valley fill shows in seismic lines high to middle angle dipping reflectors at the base and a top of sequence with an intervening low angle seismic unit. This pattern is associated with a landward migration of the seismic unit depocentres. Sedimentary facies of the main seismic units suggests an upward and landward shift from estuarine mixed sands and muds, to estuary mouth massive sands, topped by fine marine sands. The described sedimentary and seismic characters, and the Holocene age of the valley fill near the present-day Charente river mouth, suggest that the drowned Charente valley infill mainly corresponds to a single transgressive sequence emplaced during the last sea level rise. Beyond the local interest, the dense seismic grid recorded across the Charente drowned valley gives a seismic validation for the model of large valley fill proposed by Ashley and Sheridan [Ashley, G.M., Sheridan, R.E., 1994. Depositional model for valley fills on a passive continental margin. In: R.W. Dalrymple, R.J. Boyd, B.A. Zaitlin (Eds.), Incised Valley Systems: Origin and Sedimentary Sequences. SEPM (Soc. Sediment. Geol.) Spec. Publ., Tulsa, Vol. 51, pp. 285–301.]. We propose that high–low–high internal reflection pattern succession represents the “Seismic Sandwich” in reference to the Ashley and Sheridan [Ashley, G.M., Sheridan, R.E., 1994. Depositional model for valley fills on a passive continental margin. In: R.W. Dalrymple, R.J. Boyd, B.A. Zaitlin (Eds.), Incised Valley Systems: Origin and Sedimentary

* Corresponding author. Etablissement Principal du Service Hydrographique et Océanographique de la Marine, Cellule Sédimentologie 13 rue du Chatellier, BP30316 29603 Brest cedex, France.
E-mail addresses: weber@shom.fr (N. Weber), echaumil@univ-lr.fr (E. Chaumillon), tesson@univ-perp.fr (M. Tesson).

doi:10.1016/j.margeo.2004.04.001

Sequences. SEPM (Soc. Sediment. Geol.) Spec. Publ., Tulsa, Vol. 51, pp. 285–301.] "Sedimentary Sandwich". Such seismic pattern is also recognized in the Gironde valley [Mar. Geol. 175 (2001) 183.].

Keywords: high-resolution seismic; incised valley fill; sequence stratigraphy; holocene transgression

1. Introduction

Quaternary sedimentary record on low subsidence continental margins is extremely reduced (Ashley and Sheridan, 1994; Cirac et al., 1997; Lericolais et al., 2001) compared to subsiding margin settings like those located in foreland basins (Mascle and Puigdefabregas, 1998; Ridente and Trincardi, 2002). High frequency Quaternary sea level oscillations have removed or reworked recent sediments of low subsidence continental margins in two ways: (1) fluvial degradation and sediments bypass towards the outer shelf during sea level falls and lowstands (Swift et al., 1980; Nummedal and Swift, 1987; Suter et al., 1987; Chen et al., 1992; Wood et al., 1993); (2) sediment reworking by waves and tides during transgression and highstand (Swift, 1968; Pilkey et al., 1981; Walker, 1992; Allen and Posamentier, 1994; Ashley and Sheridan, 1994; Heap and Nichol, 1997; Reynaud et al., 1999)). Entrenched channels within incised valley systems are preferential sites of sedimentary deposition that shield deposits from erosion and favour their preservation (Allen and Posamentier, 1994; Ashley and Sheridan, 1994). Incised valleys provide opportunities to study stratigraphic sequences emplaced during the last sea level cycle (125–0 ky). They are also potential sediment reservoirs which are able to nourish present-day erosional coastal areas.

Some incised valleys have been studied with seismic and vibracores data, particularly on the US Atlantic continental shelf (Ashley and Sheridan, 1994; Zaitlin et al., 1994) showing evidence of fluvial erosion and valley incision during relative sea level fall. The filling of the incised valley may begin during the lowstand, but typically continues through the succeeding transgression. The transgressive systems tract forms an important component of the middle segment of the incised valley fill (Kraft et al., 1987; Allen and Posamentier, 1993; Zaitlin et al., 1994). On the storm dominated Atlantic shelves, shoreface erosion removes sediments during transgression and only the lower to middle portion of the valley-fill model proposed by Dalrymple et al. (1992) is likely to be preserved on such a passive margin (Ashley and Sheridan, 1994). A model of valley fill for small, intermediate and large valleys of the US Atlantic continental margin has been also proposed based on a case study (Ashley and Sheridan, 1994).

In mixed tide- and wave-dominated environments, the best documented example is given by the Gironde estuary (Allen and Posamentier, 1993; Allen and Posamentier, 1994). The bulk of the valley fill is transgressive and occurs in three distinct phases from land to sea: (1) inner-estuary muddy and sandy point bars and tidal flats, (2) estuary mouth sands; (3) shoreface sands and marine muds (Allen and Posamentier, 1993; Allen and Posamentier, 1994; Allen and Fenies, 1995). Seaward of the maximum flooding shoreline, inner-estuary deposits are partially eroded and overlain by thick estuary mouth tidal-inlet sands. Seismic investigations conducted across the Gironde incised valley (Lericolais et al., 1998; Lericolais et al., 2001), allow to recognize lowstand, transgressive and highstand systems tracts (Van Wagoner et al., 1988; Van Wagoner et al., 1990) bounded by key stratigraphic surfaces: Sequence Boundary (SB), Flooding Surface (FS), Tidal Ravinement Surface (TRS) and Wave Ravinement Surface (WRS).

Despite numerous incised valleys studies since the last decades, it appears that there is still a need to explore the three-dimensional stratigraphy of Quaternary fluvial systems (Blum and Tornqvist, 2000). Application of high-resolution seismic investigation is an important tool in this regard. New results from two seismic reflection surveys ground-truthed by one vibracore cruise, dedicated to the Charente incised valley, are presented here. The Charente River is located about 50 km northward of the Gironde River.

These two rivers are comparable in terms of marine hydrodynamic parameters but they strongly differ in their water discharges and catchment areas. The objective of this paper is to evidence: (1) the channel network of the drowned Charente incised valley; (2) the three-dimensional internal organization of the Charente drowned-valley fill in the inner part of its outer segment; (3) the sedimentary facies of the main seismic units; (4) a comparison of the results obtained in the Charente valley with previous studies: the Gironde valley-fill (Lericolais et al., 2001) and the model proposed by Ashley and Sheridan (1994).

2. General setting

2.1. Morphological setting

The present-day Charente River flows into the ≪Pertuis d'Antioche≫ which is located between Ré and Oléron islands. The Pertuis d'Antioche is an approximatively 10 km wide and 40 km long embayment (Fig. 1). Its seafloor morphology is characterized by a relatively deep trough, the Antioche Deep (− 40 m), isolated from the shelf by a crescent-like shoal (− 20 m deep). The inter-island shoal is the area where the seismic profiles used for this study were recorded (Fig. 2). The Antioche Deep has been interpreted as a remnant of the drowned Charente paleo-valley (Barusseau, 1973; André, 1986). According to the definition of estuary by Dalrymple et al. (1992), the Pertuis d'Antioche can be considered as the seaward part of the Charente estuary. Taking into account its morphology and hydrodynamics, the Pertuis d'Antioche consists of a wave- and tide-dominated estuary (Table 1).

2.2. Neotectonic and seismotectonic setting

Present-day seismic activity in the western part of France is moderate (Müller et al., 1992) related to the reactivation of Hercynian faults and it is often associated with isostatic or eustatic readjustments (Müller et al., 1992). Seismological activity is concentrated southward and northward of the Charente incised valley and epicentres distributions are striking in a NW–SE direction. Focal mechanisms mainly indicate dextral strike-slip displacements (Rothé, 1983). On land, fluvial morphology is controlled by neo-tectonic activity (Van Vliet-Lanoë et al., 1997). It can be noted that both the Gironde and the Charente estuaries exhibit a N300° orientation which is parallel to the morphological pattern inherited from reactivated Hercynian faults.

2.3. Hydrodynamics characteristics

The Charente and the Gironde estuaries flow into the Bay of Biscay southwest of the French Atlantic coast. They respectively drain a small and a large basin (Table 1), including the western part of the Massif Central and the northern Pyrenees Mountains. In both the Charente and the Gironde estuary mouths, semi-diurnal tides are macrotidal. Another essential hydrodynamic forcing of this inner-shelf is its exposure to large-amplitude and long period oceanic swell (Table 1).

2.4. Sedimentary infill of the Charente river mouth

The sedimentary infill of the Charente valley has been cored near the present-day mouth of the Charente River (Fig. 1). All the cores evidence that sediment emplaced upon the Mesozoic basement is younger than 9000 years BP (Table 2). This sedimentary infill constitutes an overall fining-upward succession that is interpreted as a transgressive unit emplaced at the end of the deglacial sea level rise (Carbonel et al., 1998; Decker et al., 2001) and which is capped by highstand deposits.

3. Data and methodology

3.1. Seismic data

A mini-sparker with an input energy of 50 J associated with a single-channel streamer was used. Broadband signal of the source includes frequencies ranging from 200 to 1200 Hz, thus vertical resolution of seismic records is in order of 2 m. Seismic signal has been digitised in real time and processed by using a Delph Seismic system v2.01. Seismic processing included frequency band pass filtering, gain correction and stacking of adjacent traces. Accurate positioning of each profile was provided by a differential GPS navigational system.

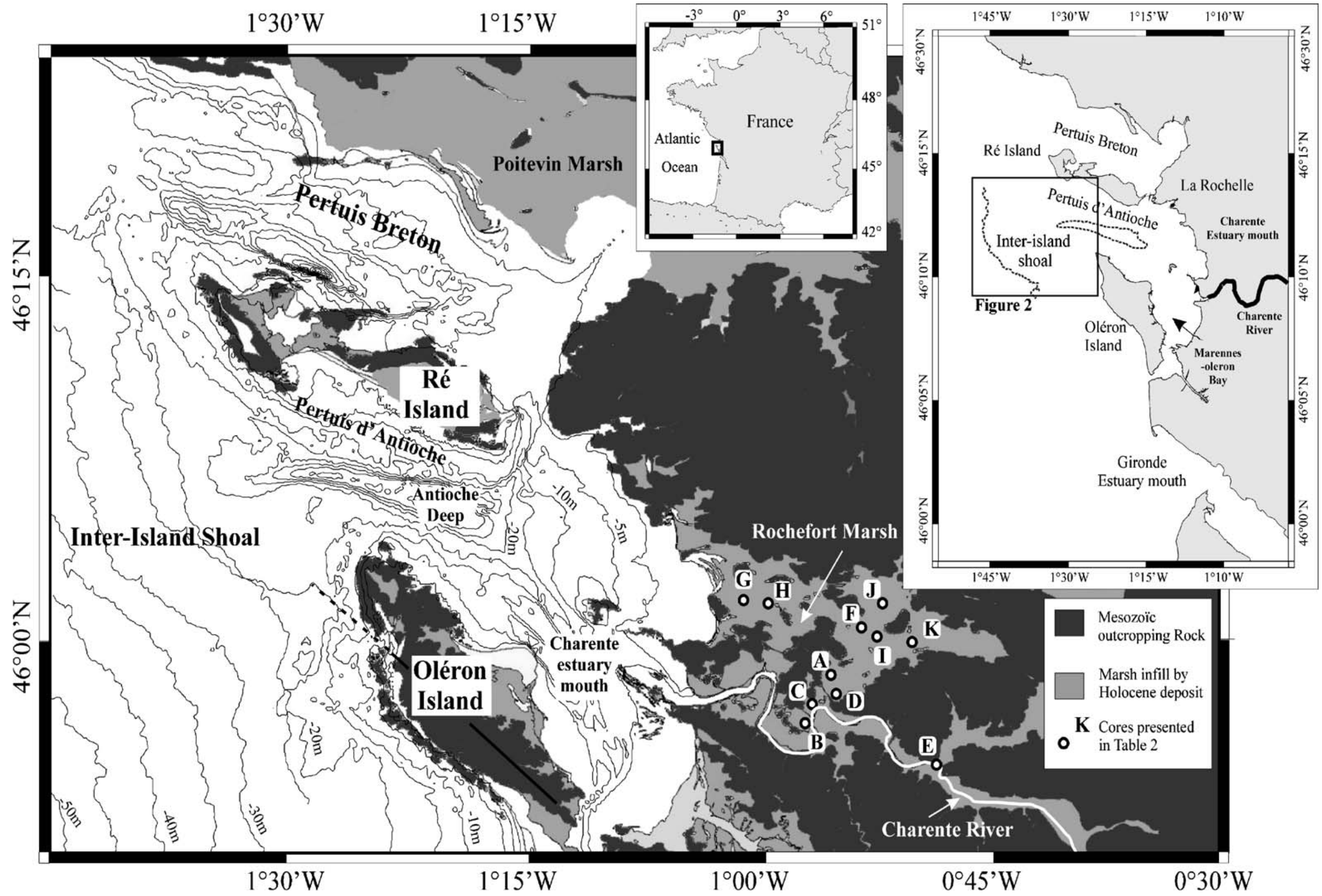


Fig. 1. Simplified bathymetric map (bathymetric spacing: 5m, Service Hydrographique et Océanographique de la Marine data) showing the location of the study area.

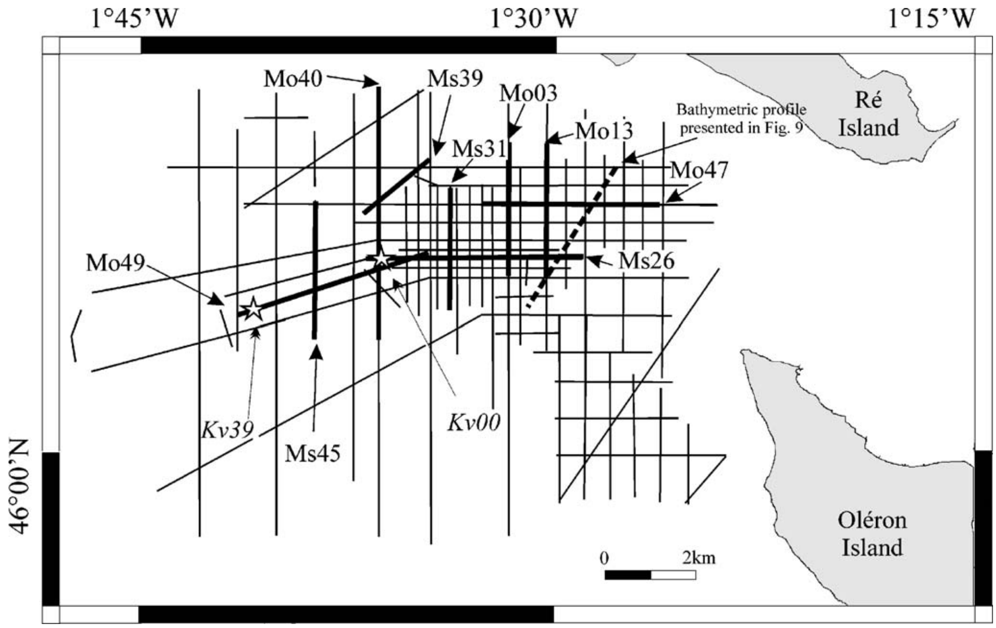


Fig. 2. Seismic profiles from SIFADO, MOBIDYC1 and MSTULR1 cruises and cores from MOBIDYC3 cruises (seismic profiles in bold are presented in this article).

A preliminary seismic survey of the inter-island shoal was conducted in July 1999 (SIFADO cruise) on board the hydrographic vessel of ≪Conseil Général de Charente maritime≫. Following those early results (Chaumillon et al., 2002), two other seismic cruises were conducted in March 2000 (MOBIDYC1) and April 2001 (MSTULR1) on board the RV ≪Côte d'Aquitaine≫ (CNRS, Institut National des Sciences de l'Univers). The final seismic grid comprises 69 seismic profiles (1260 km over an area of 1660 km^2) located apart about 1 to 2 nautical miles from each other (Fig. 2).

Table 1
Hydrodynamic parameters for the Gironde and Charente rivers mouths

	Gironde River (Lesueur et al., 2002)	Charente River (Tesson, 1973)
Drainage area (km^2)	74 000	10 000
Mean annual discharge (m^3 year^{-1})	2.5 to 3.5 × 10^{10}	3.1 × 10^9
Sediment load (t year^{-1})	1.2 to 1.5 × 10^6	0.1 × 10^6
Tide (SHOM, 1993, 2003)		
Mean neap tide height (m)	5	6
Mean spring tide height (m)	2.5	3
Max surface current velocity (m s^{-1})	0.5 to 1 in the mouth	1
Swell	large-amplitude (H_{max}>4.8 to 15 m and long period ($9<T<15$ s) swells originating from the west–northwest. An amplitude of 2 m is attained during 75% of the time from October to March (Castaing, 1981).	

Seismic analysis is based on: (1) identification of key surfaces underlined by reflection terminations: downlap, onlap, toplap, erosion truncation; (2) internal configuration of units bounded by key surfaces; (3) angles and orientation of reflectors; (4) seismic facies: amplitude, frequency, continuity. These parameters allowed the identification of seismic units and sub-units infilling the Charente-incised valley, and the reconstruction of isopachs maps of the main seismic units. For time/depth conversion, acoustic velocity of 1600 m s^{-1}, was used within the recent sedimentary cover (Pouliquen, 1992; Maroni, 1997). Isobath maps for the key stratigraphic discontinuities were also reconstructed by subtraction of different isopach maps to present-day bathymetry (SHOM data).

Table 2
Cores and dating results obtained at the present-day Charente river mouth (see Fig. 1 for core location)

Ident. in Fig. 1	Area	Depth (m)	Age BP (year)	Object	References
A	Cabane pourrie—Gif 793	− 9	4520 ± 140	Wood and Shell	(Gabet, 1973)
B	Charente valley—Gif 2244	− 6	3380 ± 110	Shell	(Gabet, 1973)
C	≪Ecluse de Rochefort≫—CPS102	− 17.5	7400 ± 170	Shell	(Carbonel et al., 1998)
D	La Challonière à Tonnay Charente—≪coupe Brigitte≫	− 1.5	7400 ± 170	Shell	(Carbonel et al., 1998)
E	Boutonne	− 4.5	7645 ± 75	Shell	(Carbonel et al., 1998)
F	Roc 2013	− 7.9	3870 ± 40	Shell	(Decker et al., 2001)
G	Roc 2003	− 4.8	4610 ± 40	Shell	(Decker et al., 2001)
H	Roc 2007	− 9.9	5240 ± 40	Shell	(Decker et al., 2001)
I	Roc 2012	− 9.5	5420 ± 80	Shell	(Decker et al., 2001)
I	Roc 2012	− 9.6	5830 ± 40	Foram.	(Decker et al., 2001)
J	Roc 2011	− 7.5	7080 ± 40	Shell	(Decker et al., 2001)
K	Courtin	− 3	8140 ± 330	Peat	(Bourgeuil, 1995)

3.2. Bathymetric data

Bathymetric data were extracted from the database of the French Hydrographic Office (Service Hydrographique et Oceanographique de la Marine: SHOM). From these data, digital elevation models were developed with grid spacing of 0.05′ min (Fig. 8D), based on the mean initial data sampling (horizontal distance of 50 to 100 m). Due to the historical importance of the port of La Rochelle, bathymetric surveys of the "Pertuis d'Antioche" have been carried out since the beginning of the 19th century. The bathymetric information from such charts can be digitised, and allows quantification of morphological change (Chaumillon et al., 2002). The reliability of measurements has been checked by the rock stability between 19th and 20th century surveys (Bertin et al., 2004). The reference level of sounding reduction is the marine chart-sounding datum at La Rochelle Port (+3.504 m with reference to Institut Géographique National 1969) (SHOM, 2003).

3.3. Vibracore data

A vibracore cruise was conducted in March 2002, aboard R/V Côte de la Manche (CNRS-INSU) to collect core samples where the main seismic units crop out at the seafloor (Fig. 2). Six cores with lengths ranging from 0.64 to 1.02 m were obtained for this purpose.

All core sections were split lengthwise and one half of the core was used for sampling while the other half was stored as an archive. Core processing include: (1) visual description and logging, (2) digital imaging via a numerical camera connected to a computer, (4) sub-sampling of sediments (each 15 cm). Grain size distribution of samples is obtained thank to a laser diffraction particle sizer (Coulter LS 230), for particles from lower than 0.00382 to 2 mm, and sieving for particles from 1.25 mm to 2 cm. Samples are characterized by calculating percent for each class (mud, silt, fine sand, sand, gravel and pebbles), granulometric parameters, mean grain size (MGZ), sorting (So) skewness (Sk), with the statistic moments method (Rivière, 1977) foraminifera and macro-benthos determination.

4. Results

4.1. Main seismic units and surfaces

Seismic facies (amplitude, frequency and continuity), internal configuration, reflectors terminations and outer shape (including thickness and volume) have been used to define five main seismic units (Figs. 3–5). Detailed description of seismic units and surfaces is summarised in Fig. 6 and Table 3.

Unit U0 is present throughout the all study area. It consists of strong amplitude and low frequency reflectors. U0 internal configuration is parallel with tilted and folded reflectors.

Unconformity R1 is an erosional surface. It is generally sub-horizontal, but it exhibits localised

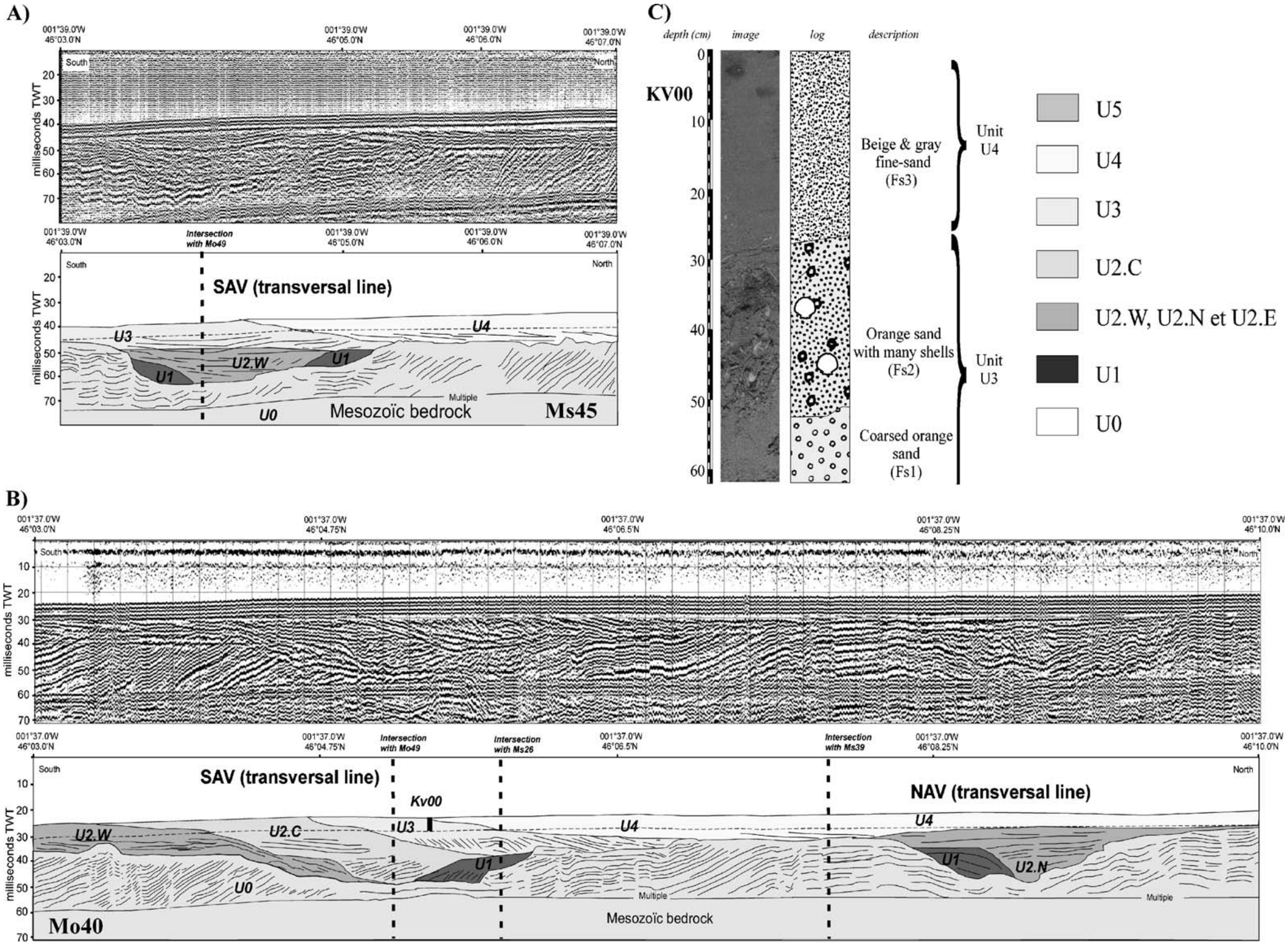


Fig. 3. Processed seismic profiles Ms45 (A) and Mo40 (B) and their interpretation showing transversal cross-sections of the SAV and NAV (for NAV and SAV location, see Fig. 7A); (C) Vibrocore KV00 photograph and granulometric results showing sedimentary facies Fs01, Fs02 and Fs03 corresponding to seismic units U3 and U4. KV00 is located on seismic profile Mo40 (A).

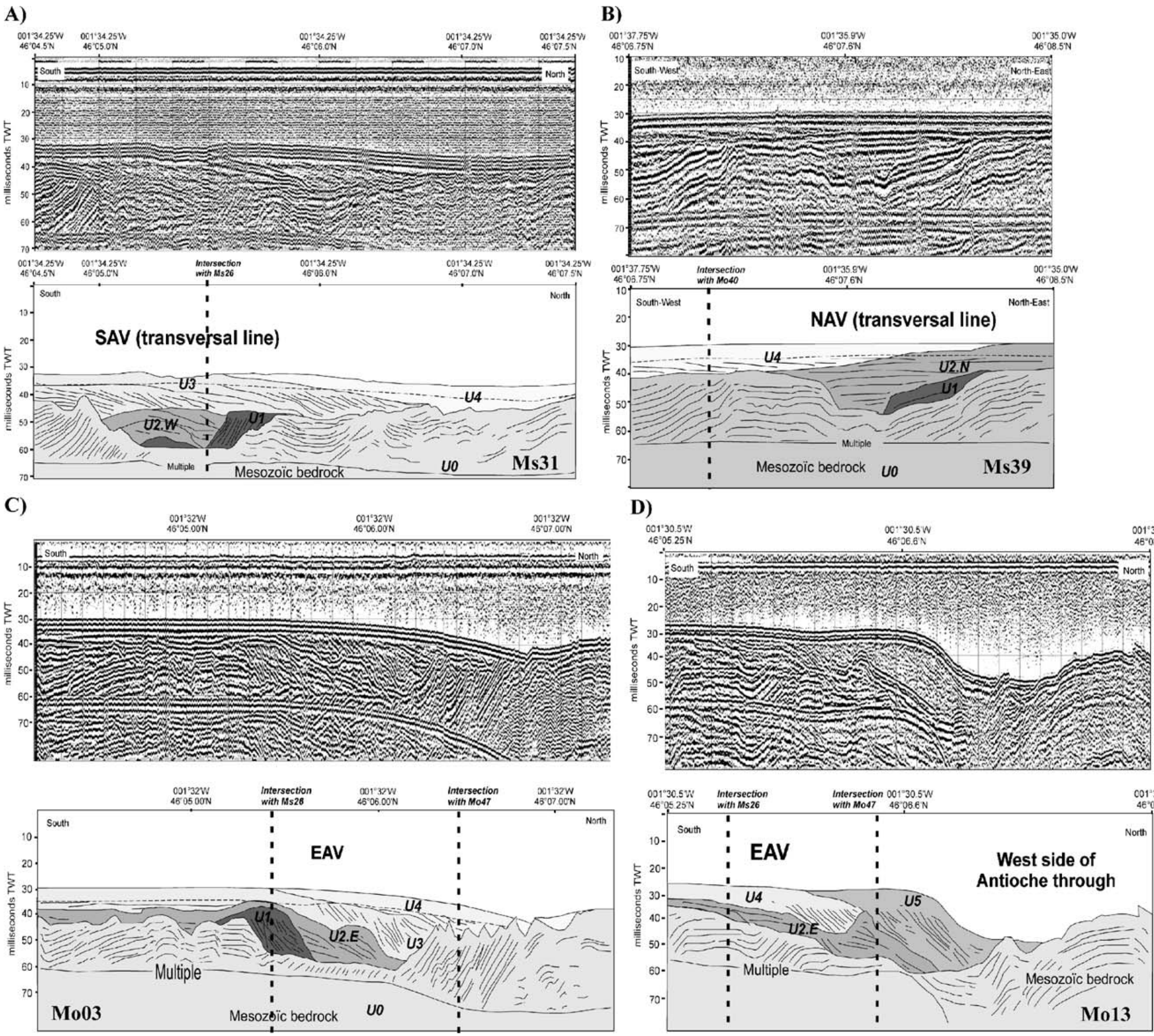


Fig. 4. Processed seismic profile Ms31 (A), Ms39 (B), Mo03 (C), and Mo13 and Ms26 (D) and their interpretation showing transversal cross-sections of the SAV, NAV and EAV (for EAV, NAV and SAV location, see Fig. 7A).

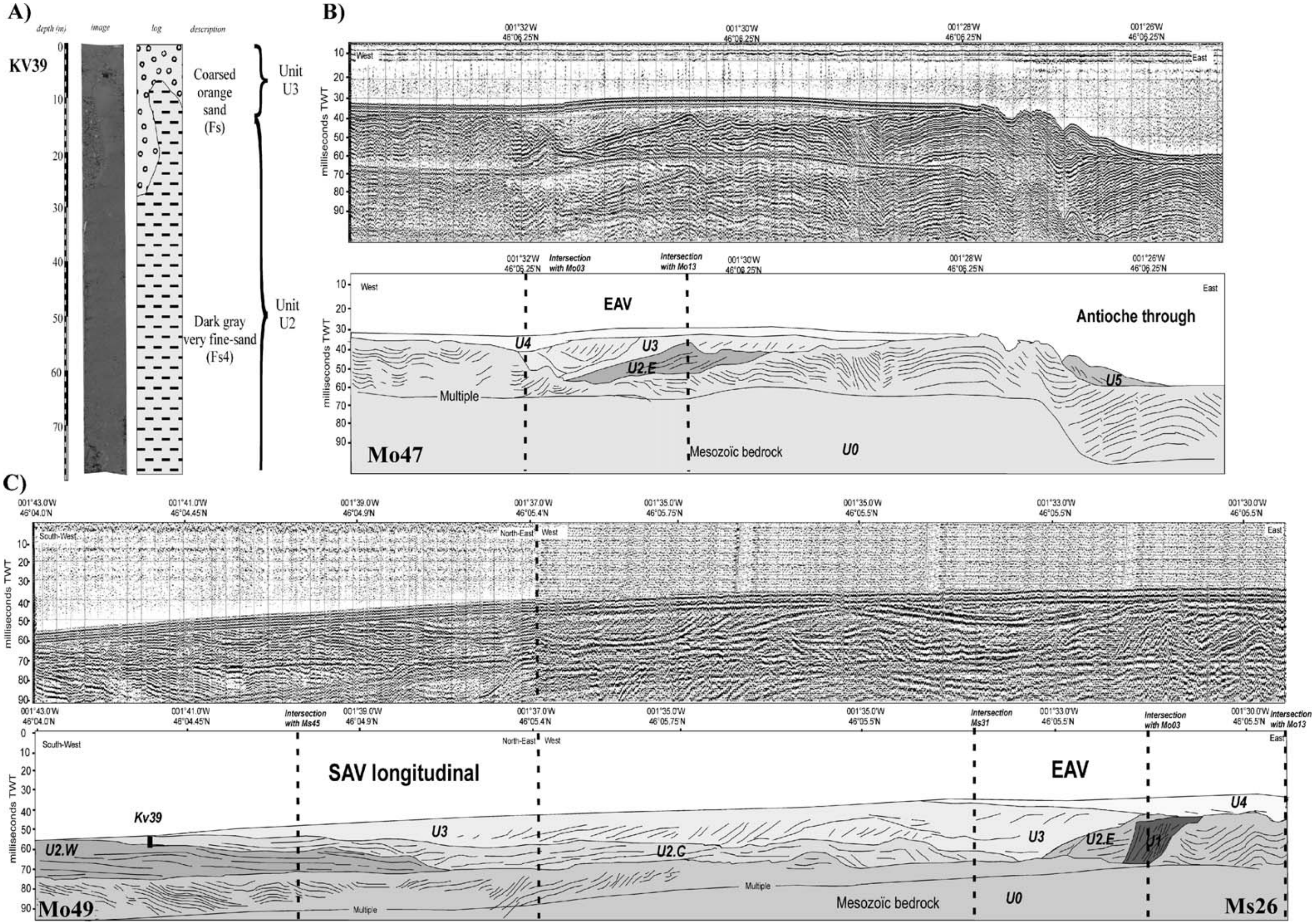


Fig. 5. (A) Vibrocore KV39 photograph and granulometric results showing sedimentary facies Fs1 and Fs4 corresponding to seismic unit U3 and U2. KV39 is located on seismic profile Mo49; processed seismic profile Mo47 (B); Mo49 and Ms26 (C) and their interpretation showing transversal and longitudinal cross-sections of the SAV and EAV (for EAV and SAV location, see Fig. 7A).

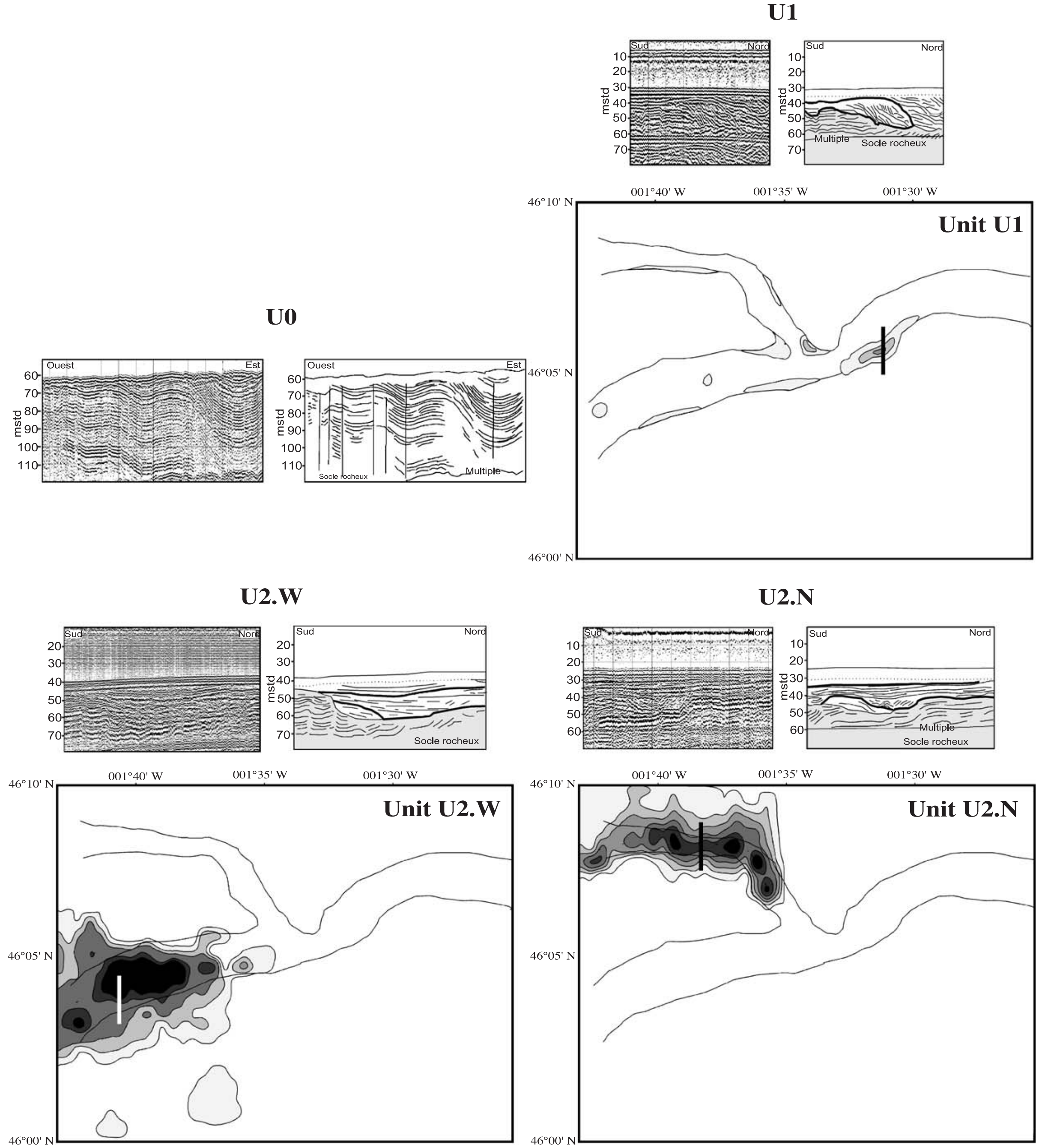


Fig. 6. Isopach maps of the main seismic units U1, U2.W and U2.N identified within the Charente drowned valley.

deep and wide incisions (depth: 27 m and width 2 to 7 km). The isobath map of R1 (Fig. 8A) evidences a meandering pattern of these incisions with wave-length of about 2 km. The connection between the ≪Antioche Deep≫ and incised channels is clear. The East Antioche Valley (EAV) constitutes the

Table 3
Seismic units characters (F: frequency; A: amplitude; C: continuity; T: top; B: bottom)

Seismic stratigraphy analysis								
Seismic unit		Reflectors characters	Reflection pattern configuration	Type of reflection terminations	True or obvious reflector dips	Outer shape	Max. thickness (m)	Volume (10^6 m^3)
U5		F: Middle A: Low C: Low	High angle Oblique Parallel	T: Toplap B: Downlap	0.70°NE	Valley slope fill	12	29
U4		F: High A: Middle C: Low	Shingled	T: Erosion B: Downlap	1°NE	Sheet drape and valley fill	14	329
U3		F: Middle A: Middle C: Middle	High angle Oblique Parallel	T: Erosion = R4 B: Downlap	1.40°NW	Valley fill	16	358
U2	C	F: Middle A: High	Sub-horizontal parallel to gently dipping	T: Erosion = R3 B: Onlap and downlap	0.40°ESE to ENE	Valley fill	9	63
	E	C: High		T: Erosion = R3 B: Onlap and downlap	0.65°NW	Valley slope fill	10	94
	N			T: Toplap B: Onlap and downlap	0.20°SSE	Valley fill	17	459
	W			T: Toplap and erosion B: Onlap and downlap	0.20 to 0.40°SE	Valley fill	19	994
U1		F: High A: Low C: Low	High angle Oblique Parallel	T: Erosion = R2 B: Onlap and Downlap	4.50°	Small packages	8	31

seaward prolongation of the Antioche Deep below the inter-island shoal. Westward, the EAV bifurcates in two major channels: (1) The wider southern channel, the South Antioche Valley (SAV) is 3.5 to 6.5 km wide and 20 to 27 m deep relative to adjacent interfluves (4 to 12 m); (2) a northern channel, the North Antioche Valley (NAV), 2.8 to 3.5 km wide and 4 to 11 m deep relative to adjacent interfluves. The channel distributary pattern below the inter-island shoal represents a transition zone between the single deeply incised Antioche Deep upstream and shallower channels downstream. Westward of the inter-island shoal, the depth of incision decreases progressively to 3 m. Moreover, the isobath map of R1 (Fig. 8A) clearly evidences an almost rectilinear escarpment, striking N300° (Fig. 1). It extends from the northwestern shoreline of Oléron Island to the northeastern boundary of the NAV. This escarpment is associated with the NAV thalweg shift with respect to the SAV-EAV thalwegs. Southward of major channels (SAV and EAV), we identify smaller incisions (1.5 to 3 km wide and 2 to 10 m deep) (Fig. 8A).

Seismic unit U1 is composed by distinct seismic sub-units (packages of seismic reflectors) of small lateral extent and isolated from each other (Fig. 6). These sub-units are localised both on the inner side of meander bends (belts) (Fig. 5, profile Ms26) or in the thalweg axis of incised channels, identified in U0 (Fig. 4, profile Ms31). U1 internal inclined reflectors generally dip away from the insides of meander bends.

Unconformity R2 at the top of U1 is characterized by toplaps or erosional truncations.

Seismic unit U2 consist of thick (12 m) (Table 3) sub-units emplaced within the seaward part of the inter-island shoal valleys (Figs. 6 and 7). Those seismic packages fill a large part of the incised channels. Based both on their location and their internal reflector dipping directions, four sub-units can be distinguished (Figs. 6 and 7): (1) sub-unit U2.W is located within the western part of the SAV (Fig. 3); (2) sub-unit U2.N is located within the NAV (Fig. 4, profile Ms39); (3) sub-unit U2.E is located south–eastward of the EAV (Fig. 4, profile Mo03 and Mo13); (4) sub-unit U2.C is located within the

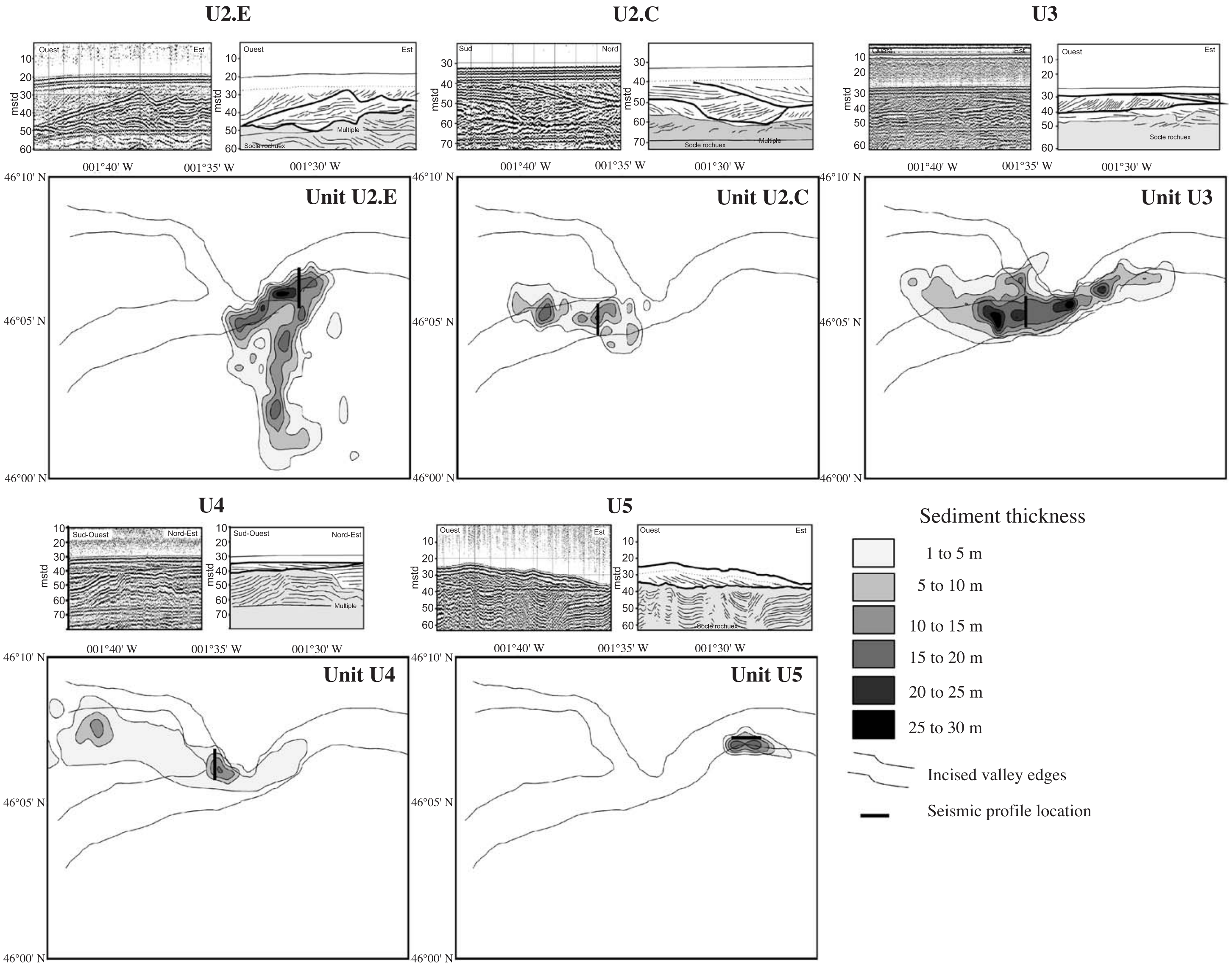


Fig. 7. Isopach maps of the main seismic units U2.E, U2.C, U3, U4 and U5 identified within the Charente drowned valley.

eastern part of the SAV (Fig. 3; profile Mo40 and Fig. 5, profile Mo49). It lies unconformably upon the eastern edge of sub-unit U2W. U2.C displays numerous internal erosion surfaces, with channelised morphologies (Fig. 3; Profile Mo40).

The principle of superposition is not applicable for the three disconnected sub-units (U2.W, U2.N and U2.E), so the relative chronology of their deposition remains unknown.

Discontinuity R3 is an erosional unconformity at the top of unit U2 with a channelised morphology (Fig. 8B). R3 underlines a single, wide (2 to 4 km) and sinuous channel. R3 channel is shifted northwestward with respect to U2.C channels.

Seismic unit U3 is a large and thick (Table 3 and Fig. 7) progradational unit, which fills the southern part of the SAV and the EAV. It shows many internal channelised unconformities of lower rank (Fig. 3, profile Mo40, 4–5).

Discontinuity R4 lies at about 3 to 5 m below the present-day seafloor at the top of unit U3. Indeed, unit U3 it is sometimes masked by the reflections from the seafloor. R4 is a planar to gently undulated erosional unconformity (Fig. 8C). It shows a shallow and almost straight channel, whose thalweg is shifted northwestward with respect to R3 channels (Fig. 8B).

Seismic unit U4 is a thin unit infilling both the R4 channel and the eastern part of the EAV (Table 3, Figs. 4 and 5 (profile Ms26) and Fig. 7). The top of U4 corresponds to the modern seafloor (Fig. 8D).

Seismic unit U5 is a shoreward progradational package (Table 3 and Fig. 7), located both in the eastern part of the inter-island shoal and against the western wall of the Antioche Deep (Fig. 4, profile Mo13). Bathymetric data have been available in U5 area since 1824 AD. Bathymetric data recorded along the same profile during both 1824 and 2001 surveys were superimposed (Fig. 9). This evidenced sediment gain in the upper part of U5 unit.

4.2. Vibracores results and correlation between sedimentary facies and seismic units

Based on the presented results, four lithofacies are distinguished based on granulometric parameters. Their main characteristics, including core number and granulometric parameters, are indicated in Table 4 and Fig. 10.

Fs1 (*Well sorted Coarse orange sand*) consists of coarse (66%; mean grain size (MGZ) = 700–800 μm) and medium sands (31%).

Fs2 (*Moderately sorted Orange sand with broken shells*) consists of medium (74%; MGZ = 400 μm) and coarse sands (16%). It includes many large (>2 cm) broken marine shells.

Fs1 and Fs2 are correlated with the upper part of seismic unit U3 (Figs. 3 and 5).

Fs3 (*Moderately sorted beige and grey fine sand*) consists of medium and fine sands (MGZ: 196 μm). Fs3 is correlated with the upper part of the seismic unit U4 (Fig. 3).

Fs4 (*Moderately sorted very fine sand (113 μm) with mud*) consists of fine sands (43%—MGZ: 196 μm) and mud (5%). The dark colour seems to be induced by organic matter. Foraminifera (*Elphidium macellum, Miliolinella subrotunda, Quinqueloculina lamarckiana* and *Adelosina longirostra*) and macrobenthos (*Tellina tenuis, Venus fasciata, Tellina* spp., *Pharus legumen* and *Echinocardium cordatum*) are identified in this sedimentary facies. Fs4 is correlated with the upper part of the seismic unit U2 (Fig. 5).

5. Interpretation

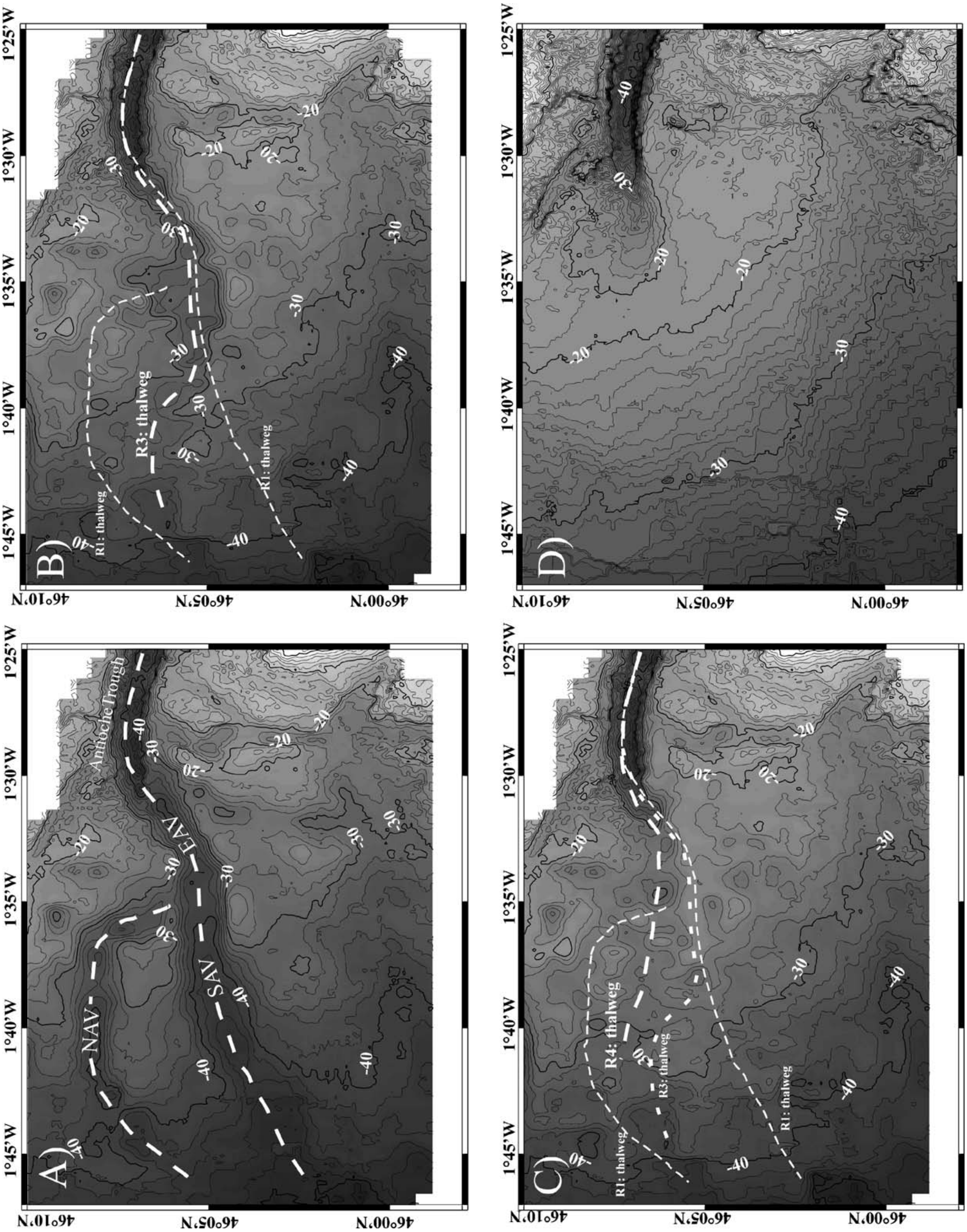
5.1. Stratigraphic interpretation

5.1.1. Morphology of the incised bedrock

Reflectors of U0 crop out close to the shore and consist of folded and faulted Mesozoic strata (Figs. 3–5) (Chaumillon et al., 2000, 2002). The U0 upper boundary, R1, is a regional erosional surface that also forms the base of the different channel-fills.

The newly described incised channels (EAV, SAV, NAV) show a meandering pattern and are connected with the Antioche Deep and the Charente River Mouth (Weber et al., 2003). Thus, they could represent a drowned incised valley segment that corresponds to large valley class sensu Ashley and Sheridan (1994).

R1 can be correlated with the regional surface of erosion, recognized onland and emplaced upon Mesozoic or Cenozoic strata. Near the modern Charente


A)
B)
C)
D)
NAV
EAV
SAV
R1: thalweg
R3: thalweg
R4: thalweg
1°25'W
1°30'W
1°35'W
1°40'W
1°45'W
46°10'N
46°05'N
46°00'N
-20
-30
-40

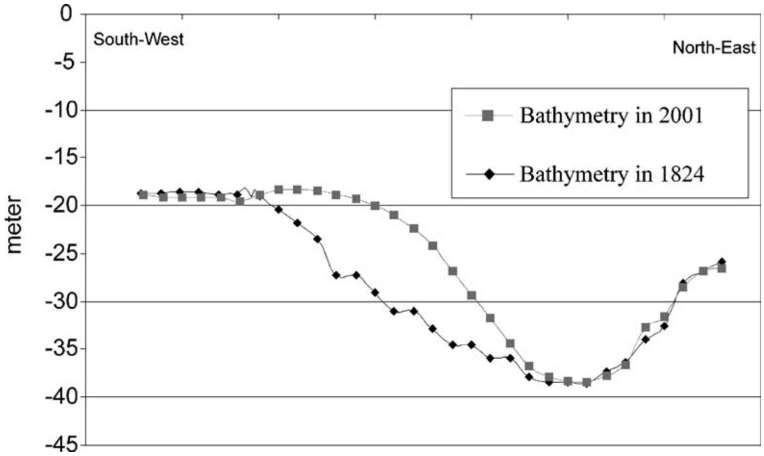


Fig. 9. Bathymetric profiles across U5 seismic Unit recorded in 1824 and 2001 AD.

river mouth, cores indicate that unconsolidated sediments deposited upon this erosonial truncation are Holocene in age (Bourgeuil, 1995; Carbonel et al., 1998; Decker et al., 2001).

5.1.2. Sedimentary infill

5.1.2.1. Unit U1: fluvial and/or tidal environment. Above R1, U1 is represented by disconnected high angle clinoforms located both at the base of the thalwegs or on the insides of meander bends. They could be interpreted as point bars deposits emplaced in an alluvial or a tidal environment.

5.1.2.2. Units U2 and U3: estuarine environment. U2 and U3 are the thickest and the largest units. They constitute the bulk of the valley fill.

U2 constitutes the bulk of the seaward part of the valley fill (SAV and NAV). Upper U2 sedimentary facies corresponds to mixed very fine sand and mud. It includes estuarine foraminifera (*E. macellum* and *M. subrotunda*), which are typical of semi-enclosed coastal environments. Consequently, horizontal to gently dipping reflectors of U2, displaying strong acoustic impedance variations, could be interpreted as estuarine tidal sand and mud alternations (Allen and Posamentier, 1993, 1994).

U3 constitutes the bulk of the eastern part of the SAV. Its upper part consists of coarse to medium sands with marine broken shells, recording marine influence. U3 systematically displays deep (10 m) internal channelised erosional surfaces. Such features identified both at the top of U2.C and U3 (R3 and R4 surfaces) could be interpreted as Tidal Ravinement Surfaces—TRS. Marine sedimentary facies of U3 is associated with TRS, this allows us to interpret seismic unit U3 as estuary mouth massive sands cut by tidal inlets.

5.1.2.3. U4: marine deposition. At the top of U3, R4 erosional truncation shows a shallow channel and extends outside the underlying valleys and channels, within interfluve areas, where it exhibits an almost planar geometry. Such features lead us to interpret R4 as an amalgamation between a TRS and a Wave Ravinement Surface—WRS (Swift, 1968; Allen and Posamentier, 1994; Ashley and Sheridan, 1994). U4 is a sheet drape composed by fine sands including marine shells and overlying R4. It is interpreted as a marine environment record.

Fig. 8. Isobath maps of the unconformities identified between the main seismic units: (A) Isobath map of the mesozoïc bedrock erosional surface (R1 surface). (B) Isobath map of U2 upper boundary (R3 surface) merged with R1 unconformity; R3 is interpreted as a tidal ravinement surface. (C) Isobath map of U3 upper boundary (R4 surface) merged with R1 unconformity. R4 is interpreted as an amalgamation between a tidal ravinement surface and a wave ravinement surface. (D) Present-day Bathymetry. Dashed lines correspond to incised valley thalwegs at the top the Mesozoic bedrock.

Table 4
Main sedimentary facies characteristics (M: mud; Si: silt; Sa: very fine sands; FS: fine sands; S: sands; CS: coarse sands; G: gravel; P: pebbles; MGZ: mean grain size; So: sorting; Sk: skewness)

Sedimentary analysis														
Facies	Description	Cores and samples	Granulometric composition								MGZ (μm)	So	Sk	Seismic unit
			M	Si	Sa	FS	S	CS	G	P				
Fs4	Very fine sand and mud	Bottom Kv39	2	3	30	43	22	2	0	0	136	0.86	2.22	U2W
Fs3	Beige and grey fine-sand	Top Kv00	0	0	9	38	47	6	0	0	241	0.86	1.81	U4
Fs2	Orange sand with broken shells	Middle Kv00 and top Kv39	0	0	1	7	74	16	2	1	460	0.75	2.76	U3
Fs1	Coarse orange sand	Bottom Kv00	0	0	0	1	31	66	1	0	456	0.64	1.87	U3

5.1.2.4. U5: present-day marine reworking and deposition. U5 is the upper most unit and consists of high angle clinoforms displaying an eastward progradational package. Present-day high energy hydrodynamics (large storm wave amplitude associated with tidal currents) and the outcrop at the seafloor of valley-fill basal units (U2 and U3) suggest that present-day seafloor of the inter-island shoal corresponds to a wave ravinement surface. This present-day high energy hydrodynamics could lead to seaward sand bed load transport and sediment gain of U5 since 1824 (Barusseau, 1973). U5 would record modern infilling of the Antioche Trough.

Correlations between seismic units and cores have shown that: (1) low angle unit (U2) consists of mixed sands and muds and (2) high angle units (U3 and U4) consist of sands. If we consider that U1 (high angle unit) consists of coarse sands, then the seismic pattern of the Charente valley (high angle seismic units at base and top with an intervening low angle seismic unit) would be similar to the "sedimentary sandwich" depicted within large valleys of the US Atlantic continental margin (Fig. 12) (Ashley and Sheridan, 1994). The valley fill described by these authors is composed by: Sands and gravels at the base, sands at the top with an intervening mud unit. The Charente

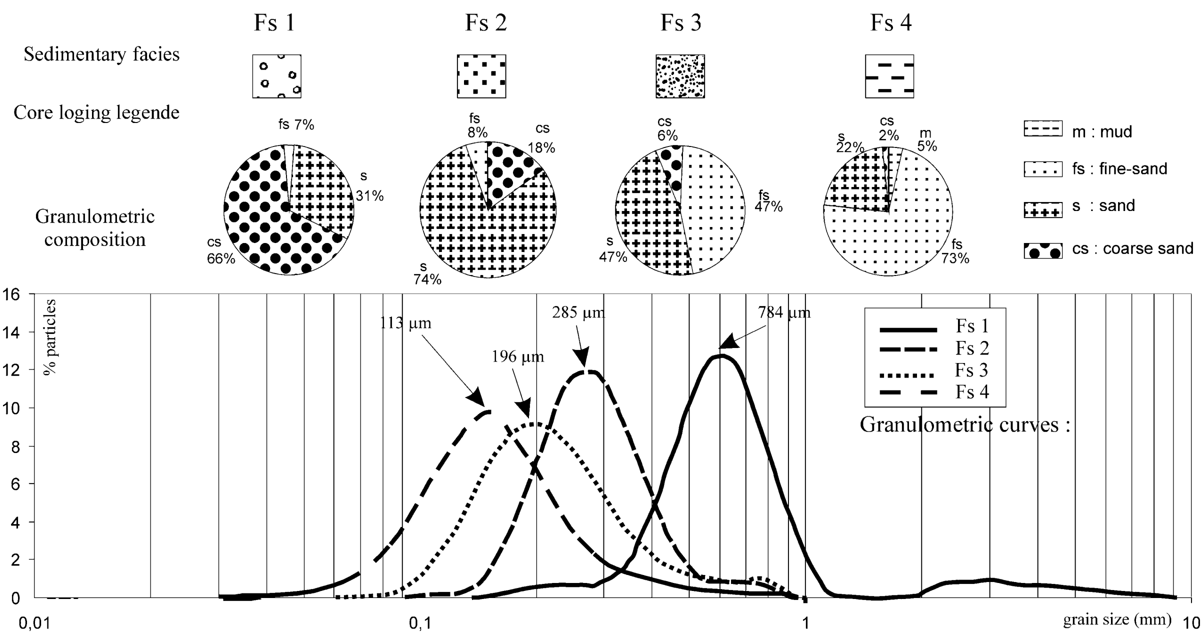


Fig. 10. Sedimentary facies and granulometric curves for the main sedimentary units.

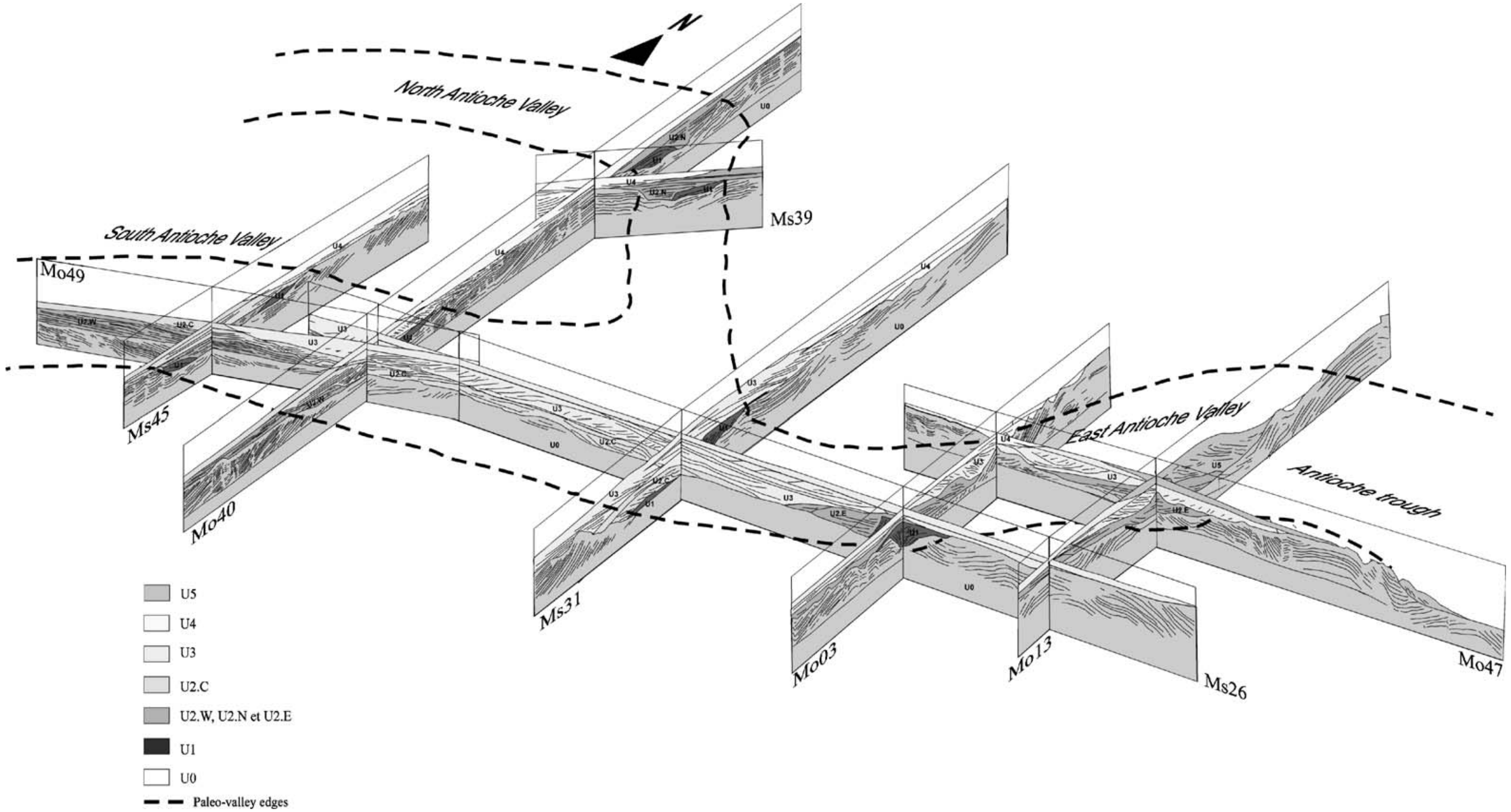


Fig. 11. Fence Diagram built thank to seismic lines Mo13, Mo03, M40, Mo47, Mo49, Ms26, Ms31, Ms39 and Ms45. The black doted lines indicate the boundaries of the incised valleys.

incised valley-fill organization would represent a seismic validation of Ashley and Sheridan (1994) valley-fill model. This high–low–high angle internal reflection pattern succession is named "Seismic Sandwich" in reference to the Ashley and Sheridan "Sedimentary Sandwich". It would represent the typical internal architecture of a single transgressive sequence within large incised valleys (Fig. 11).

5.2. Sequence stratigraphic interpretation

Considering that the shelf break is around 150 mbsl (meter below sea level) in the Bay of Biscay (Sibuet et al., 1994) and that the sea-level was around 120 mbsl during the last glacial maximum (Hernandez-Molina et al., 2000), R1 is interpreted as a sequence boundary SB2 (Posamentier et al., 1988; Posamentier and Vail, 1988) emplaced during quaternary lowstands (Chaumillon et al., 2000, 2002) and probably reactivated during the last sea-level lowstand.

Major results of the drowned Charente valley sedimentary infill, include:

- an internal reflection pattern evolution including, high to middle angle dipping reflectors (U1, U3, U4, U5) at the base and top of the valley-fill with an intervening horizontal to low angle dipping reflectors unit (U2);
- landward migration of successive depocentres from U2 to U5;
- upward and landward shift in sedimentary facies from estuarine mixed sands and muds (U2), to estuary mouth massive sands (U3), topped by marine fine-sands (U4);
- a northeastward shift of TRS thalwegs, located within and at the top of U2.C and U3.

From those results, we propose that the Charente drowned valley infill could record a retrogradational sequence emplaced during transgression. Taking into account that sedimentary infill cored near the modern Charente mouth is only Holocene in age (Carbonel et al., 1998; Decker et al., 2001), the drowned valley infill, identified in this study, has probably been emplaced mainly during the last sea level rise. Nevertheless, because of the lack of time constraint, we cannot exclude that: (1) the Charente valley-fill contains older sediments; (2) some discontinuities and sequences evidenced during this study originated from autogenic factors.

6. Comparison between the Charente and the Gironde incised valley

The Charente and Gironde (Fig. 3, line 45 in Lericolais et al., 2001) incised valleys depth and width were compared at a similar distance with respect to the present-day river mouth, which is about 25 km. Despite important catchments and discharge differences between the two rivers, incised valley morphology similarities are evidenced concerning their depth (20 to 25 m) and width (4.5 to 5.5 km). This observation supports the idea that correlation between valley width and modern hydrology is poor (Schumm and Ethridge, 1994). Valley dimensions are strongly constrained by their age and increase with time (Schumm and Ethridge, 1994). The Gironde and Charente-incised valley morphology similarities are also evidenced for the seaward incision decrease (Fig. 8A). Such changes in fluvial channel morphologies have been shown for the English Channel Paleo-river (Lericolais et al., 1996). This supports the idea that rivers do not always generate continuous cross-shelf incised valleys during phases of relative sea-level fall (Wescott, 1993; Talling, 1998). It has been proposed that rapid sea level fall prevents continuous fluvial erosion (Koss et al., 1994; Lericolais et al., 1996). An alternative explanation is that maximum erosion occurs where convex topography is aerially exposed (Talling, 1998). In our studied area, this convex topography corresponds to the present-day shoreline and the shoreface, that is, the inter-island shoal and Antioche Deep areas. Moreover, maximum incision depth is located within the Antioche Deep and indicates that the fluvial profile is locally reversed. This incised segment below the base level could be explained by tidal scouring (Liu et al., 1998) and tidal currents amplification related to coastline convergence.

The Charente paleo-valley exhibits a seaward distributary pattern where the main channel, constituted by the Antioche Through and the EAV, bifurcates seaward in two major valleys (Fig. 8B). The longitudinal morphology of this channel network shows a broken line pattern that we propose to be tectonically controlled. Moreover the thalweg shift of the NAV with respect to the EAV is associated with a N300 escarpment. Such morphology could record a dextral strike slip thalweg shift. The SAV would then correspond to channel avulsion in response to NAV-EAV thalweg shift.

Moreover, the Gironde incised valley, located 50 km southward of the Charente incised valley, has already been studied (Allen and Posamentier, 1993, 1994; Lericolais et al., 2001). Those authors interpret the Gironde valley fill as a single sequence linked to a fifth-order cycle (20 ky) (Fig. 12).

Comparison between seismic units of the Gironde (Lericolais et al., 2001) and Charente infills evidences strong similarities in terms of sedimentary architecture. Both internal reflection pattern evolutions show high to middle angle dipping reflectors (U1, U3, U4, U5 for the Charente valley/S1, S3, S4 for the Gironde valley) at the base and top of sequence with an intervening horizontal to low angle dipping reflectors unit (U2 for the Charente valley/S2 for the Gironde valley). Those similarities also support the idea that the Charente valley fill would represent a single sequence emplaced during the last sea level rise.

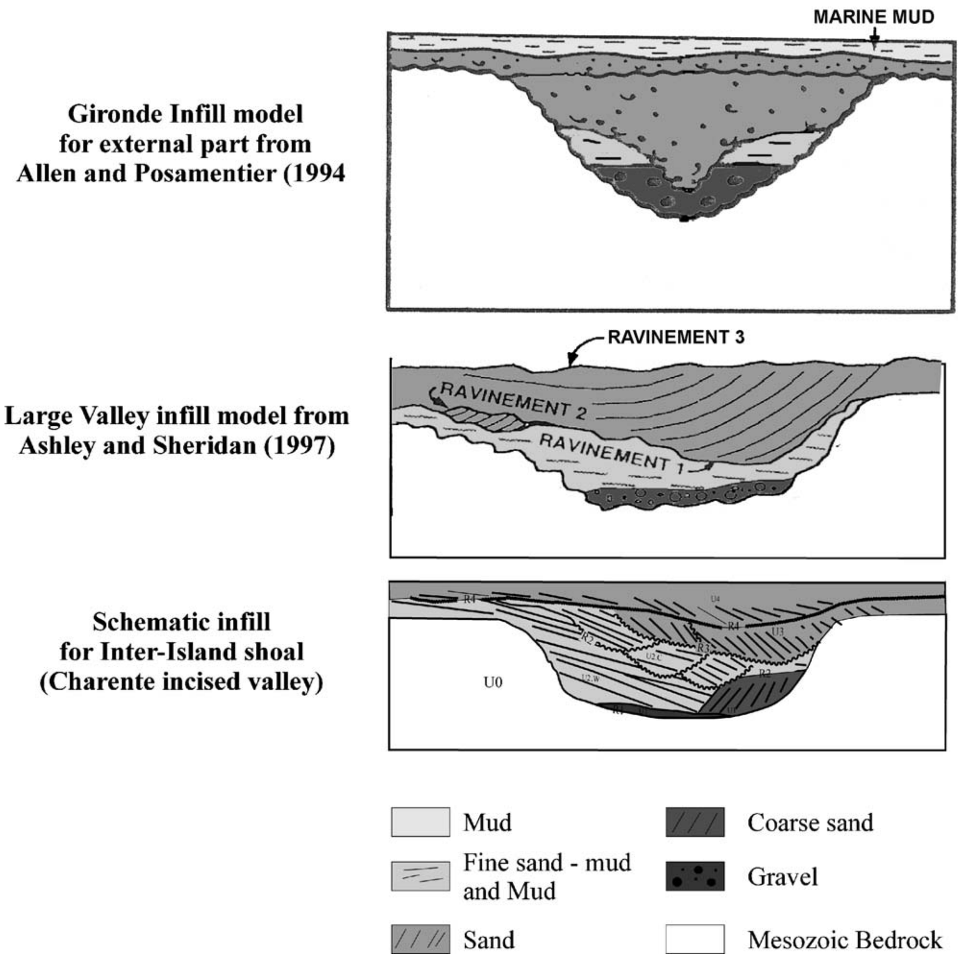


Fig. 12. Comparison between the incised valley infill models proposed by Allen and Posamentier (1994) and Ashley and Sheridan (1994) and the incised valley infill model deduced from this study.

7. Conclusion

The use of a dense high-resolution seismic grid, ground-truthed by vibracores, brings new insights on the Charente river-incised valley.

The drowned Charente incised valley morphology is evidenced for the first time. It shows similarities, with the Gironde-incised valley. This supports the idea that valley dimensions are constrained by their age rather than present-day hydrodynamic parameters. The channel network of the Charente incised valley shows a seaward distributary pattern which probably results from tectonically control. In addition, the fluvial profile is locally reversed and can be interpreted as the result of tidal scouring.

The Charente valley infill shows an upward and landward shift in sedimentary facies from estuarine mixed sands and muds, to estuary mouth massive sands, topped by marine fine-sands. Successive Depot-centres evidence a landward migration of seismic units. It is associated with an internal reflection pattern evolution, characterized by high to middle angle dipping reflectors at the base and top of sequence, with an intervening low angle seismic unit. Those sedimentary and seismic characters and the Holocene age of the valley fill near the present-day Charente estuary mouth would indicate that the infill of the Charente drowned valley corresponds to a single transgressive sequence emplaced during the last sea level rise.

Beyond the local interest, this seismic study of the Charente drowned valley gives a seismic validation for the model of large valley fill proposed by Ashley and Sheridan (1994). We propose that high–low–high internal reflection pattern evolution succession represents the "Seismic Sandwich" in reference to the Ashley and Sheridan "Sedimentary Sandwich" (Ashley and Sheridan, 1994). Such seismic pattern is also recognized in the Gironde valley (Lericolais et al., 2001).

Acknowledgements

The authors wish to thank the officer and crew of RV *Côte d'Aquitaine*, RV *Côte de la Manche* (CNRS/INSU), and RV *Les Deux Mouettes* (Conseil Général de Charente Maritime). This study has been supported by CNRS-INSU (Institut des Sciences de l'Univers); the French Hydrographic and Oceanographic Office (SHOM) (convention E61/99), GDARGOS and CEFREM of Perpignan University. We wish to thank Bureau de Recherches Geologiques et Minières (BRGM), M.J.P. Debenay (Angers university) and M.P. Barrier (IGAL) for the determination of both foraminifera and macro-benthos. We also want to thank Dr. S. Berné and Dr. A. Cattaneo for their useful suggestion which provided great improvements to the first draft of this manuscript.

References

Allen, G.P., Fenies, H., 1995. Sequence stratigraphy and facies patterns in Holocene incised valley systems: the Gironde Estuary, Arcachon lagoon and Aquitaine coast. 16th Regional Meeting of Sedimentology—5 ième Congrés Français de Sédimentologie-ASF; Field Trip Guide Book, Aix les Bains, vol. 23. IAS, Paris, pp. 94–142.

Allen, G.P., Posamentier, H.W., 1993. Sequence stratigraphy and facies model of an incised valley fill: the Gironde Estuary, France. Journal of Sedimentary Petrology 63, 378–391.

Allen, G.P., Posamentier, H.W., 1994. Transgressive facies and sequence architecture in mixed tide and wave-dominated incised valleys: example from the Gironde estuary, France. In: Dalrymple, R.W., Boyd, R.J., Zaitlin, B.A. (Eds.), Incised Valley Systems: Origin and Sedimentary Sequences. Soc. Sediment. Geol. Spec. Publ., vol. 51. SEPM, Tulsa, pp. 226–240.

André, X., 1986. Elaboration et analyse de cartes bathymétriques détaillées du proche plateau Vendéo-Charentais (Golfe de Gascogne)—Reconstitution des paléorivages de la transgression Holocène. Thèse de Doctorat de 3ième cycle. Univ. Bordeaux I, Bordeaux. 274 pp.

Ashley, G.M., Sheridan, R.E., 1994. Depositional model for valley fills on a passive continental margin. In: Dalrymple, R.W., Boyd, R.J., Zaitlin, B.A. (Eds.), Incised Valley Systems: Origin and Sedimentary Sequences. Soc. Sediment. Geol. Spec. Publ., vol. 51. SEPM, Tulsa, pp. 285–301.

Barusseau, J.P., 1973. Evolution du plateau continental rochelais (Golfe de Gascogne) au cours du Pléistocène terminal et de l'Holocène. Thèse, Univ. Bordeaux I, Bordeaux.

Bertin, X., Chaumillon, E., Weber, N., Tesson, M., 2004. Morphological evolution and coupling with bedrock substratum and mixed energy tidal inlet: the Maumusson Inlet, France. Marine Geology 204, 187–202.

Blum, M.D., Tornqvist, T.E., 2000. Fluvial responses to climate and sea-level change: a review and look forward. Sedimentology 47, 2–48.

Bourgeuil, B., 1995. Datation au radiocarbone de niveaux tourbeux holocènes du marais de Rochefort. Variation du niveau marin au cours du 9ième millénaire BP. Géologie de la France, 77–80.

Carbonel, P., Dartevelle, H., Evin, J., Gruet, Y., Laporte, L., Marambat, L., Tastet, J.P., Vella, C., Weber, O., 1998. Evolution paléogéographique de l'estuaire de la Charente au cours de l'Holocène. In: Laporte, L. (Ed.), L'estuaire de la Charente de la Protohistoire au Moyen Age. La Challonnière et Mortantambe (Charente Maritime). MSH, Paris, pp. 15–25. Vol. Daf N°72.

Castaing, P., 1981. Le transfert à l'océan des suspensions estuariennes: Cas de la Gironde. Thèse d'état, Univ. Bordeaux I, Bordeaux. 530 pp.

Chaumillon, E., Tesson, M., Weber, N., Garlan, T., 2000. Indication of the last sea level lowstand and Holocene transgression on the Charente coast: preliminary results of the SIFADO seismic cruise. In: Trentesaux, A., Garlan, T. (Eds.), Marine Sandwave Dynamics, International Workshop; March 23–24 2000, Univ. Lille 1, France, pp. 43–46.

Chaumillon, E., Gillet, H., Weber, N., Tesson, M., 2002. Evolution temporelle et architecture interne d'un banc sableux estuarien: la longe de Boyard (Littoral Atlantique, France). Comptes Rendus de l'Académie des Sciences 334, 119–126.

Chen, Z.Q., Hobbs, C.H.I., Kimball, S., 1992. An investigation of Late Pleistocene paleochannel systems in the shelf, south of Chesapeake Bay mouth. EOS Transaction, American Geophysical Union 72, 68.

Cirac, P., Berné, S., Lericolais, G., Weber, O., 1997. Séquences de dépôt dans le Quaternaire terminal du plateau Nord Aquitain (Océan Atlantique, France). Bulletin de la Société Géologique de France 168 (6), 717–725.

Dalrymple, R.W., Zaitlin, B.A., Boyd, R., 1992. Estuarine facies models: conceptual basis and stratigraphic implications. Journal of Sedimentary Petrology 62 (6), 1130–1146.

Decker, L., Le Strat, P., Karnay, G., Bourgine, B., Vairon, J., 2001. Géométries et dynamique de remblayage de l'incision holocène dans le marais de Rochefort: modélisation géologique. BRGM/RP-51007-FR. BRGM, Orléans.

Gabet, C., 1973. Nouveau témoignage des variations du niveau marin dans le maris d'Arvert. Annales de la Société des Sciences Naturelles de Charente Maritime 5, 293–302.

Heap, A.D., Nichol, S.L., 1997. The influence of limited accommodation space on the stratigraphy of an incised-valley succession: Weiti river estuary, New Zealand. Marine Geology 144, 229–252.

Hernandez-Molina, F.J., Somoza, L., Lobo, F.J., 2000. Seismic stratigraphy of the Gulf of cadiz continental shelf: a model for Late Quaternary very high-resolution sequence stratigraphy and response to sea-level fall. In: Hunt, D., Gawthorpe, R.L.G. (Eds.), Sedimentary Responses to Forced Regressions. Geologic Society of London Special Publication, vol. 172, pp. 329–361.

Koss, J.E., Ethridge, F.G., Schumm, S.A., 1994. An experimental study of the effects of base-level change on fluvial coastal plain and shelf systems. Journal of Sedimentary Research B64, 90–98.

Kraft, J.C., Chrzasrowski, M.J., Belknap, D.F., Toscano, M.A., Fletcher, C.H., 1987. The transgressive barrier-lagoon coast of Delaware: morphostratigraphy, sedimentary sequences and responses to relative rise in sea level. In: Nummedal, D., Pilkey, O.H., Howard, J.D. (Eds.), Sea-Level Fluctuation and Coastal Evolution. Soc. Sediment. Geol. Spec. Publ., vol. 41. SEPM, Tulsa, pp. 129–143.

Lericolais, G., Guennoc, P., Auffret, J.P., Bourillet, J.F., Berné, S., 1996. Detailed survey of the western end of the hurd deep (English Channel): new fact for a tectonic origin. In: De Batist, M., Jacobs, P.E. (Eds.), Geology of Siliciclastic Shelf Seas. Geologic Society of London Special Publication, vol. 117, pp. 203–215.

Lericolais, G., Fénies, H., Tastet, J.P., Berné, S., 1998. Reconnaissance par stratigraphie sismique haute résolution de la paléovallée de la Gironde sur le plateau continental. Comptes Rendus de l'Académie des Sciences 326, 701–708.

Lericolais, G., Berné, S., Fénies, H., 2001. Seaward pinching out and internal stratigraphy of the Gironde incised valley on the shelf (Bay of Biscay). Marine Geology 175, 183–197.

Lesueur, P., Tastet, J.P., Weber, O., 2002. Origin and morpho-sedimentary evolution of a fine-grained modern continental shelf deposits: the Gironde mud fields (Bay of Biscay, France). Sedimentology 49, 1299–1320.

Liu, Z.X., Xia, D.X., Berné, S., Wang, K.Y., Marsset, T., Tang, Y.X., Bourillet, J.-F., 1998. Tidal deposition systems of China's continental shelf, with special reference to the eastern Bohai Sea. Marine Geology 145, 225–253.

Maroni, C., 1997. Détermination automatique de la stratification des fonds sous-marins à l'aide d'un sondeur de sédiment. Thèse d'électronique. Université de Bretagne Occidentale, Brest. 261 pp.

Mascle, A., Puigdefabregas, C., 1998. Tectonics and sedimentation in foreland basins; results from the Integrated Basins Studies project. In: Mascle, A., Puigdefabregas, C., Luterbacher, H.P., Fernadez, M. (Eds.), Cenozoic foreland basins of Western Europe. Geological Society, Spec. Publ., vol. 134, pp. 1–28.

Müller, B., Zoback, M.L., Fushs, K., Mastin, L., Gregersen, S., Pavoni, N., Stephanansson, O., Ljunggren, C., 1992. Regional patterns of tectonic stress in Europe. Journal of Geophysic Research 97 (11), 783–803.

Nummedal, D., Swift, D.J.P., 1987. Transgressive stratigraphy at sequence-bounding unconformities: some principles derived from Holocene and Cretaceous examples. In: Nummedal, D., Pilkey, O.H., Howard, J.D. (Eds.), Sea-Level fluctuation and Coastal Evolution. Soc. Sediment. Geol. Spec. Publ., vol. 41. SEPM, Tulsa, pp. 241–260.

Pilkey, O.H., Blackwelder, B.W., Knebel, H.J., Ayers, M.W., 1981. The Gorgia embayment continental shelf: stratigraphy of a submergence. Geological Society of America Bulletin 92, 52–63.

Posamentier, H.W., Vail, P.R., 1988. Eustatic controls on clastic deposition: II. Sequence and systems tract models. In: Wilgus, C.K., et al. (Eds.), Seal-level Changes: An Integrated ApproachSoc. Sediment. Geol. Spec. Publ., vol. 42. SEPM, Tulsa, pp. 125–154.

Posamentier, H.W., Jersey, M.T., Vail, P.R., 1988. Eustatic controls on clastic deposition: I. Conceptual framework. In: Wilgus, C.K., et al. (Eds.), Seal-level Changes: An Integrated Approach. Soc. Sediment. Geol. Spec. Publ., vol. 42. SEPM, Tulsa, pp. 109–124.

Pouliquen, E., 1992. Identification des fonds marins superficiels à l'aide de signaux d'écho-sondeurs. Thèse, Univ. Denis Diderot, Paris, 7.

Reynaud, J.-Y., Tessier, B., Proust, J.-N., Dalrymple, R., Marsset, T., De Batist, M., Bourillet, J.-F., Lericolais, G., 1999. Eustatic and hydrodynamic controls on the architecture of the deep shelf sand bank (Celtic Sea). Sedimentology 46, 703–721.

Ridente, D., Trincardi, F., 2002. Eustatic and tectonic control on deposition and lateral variability of Quarternary regressive sequences in the Adriatic basin (Italy). Marine Geology 184, 273–293.

Rivière, A., 1977. Méthodes granulométriques; techniques et interprétations. Masson, Paris. 170 pp.

Rothé, J.-P., 1983. Sismicité de la France entre 1971 et 1977, Strasbourg.

Schumm, S.A., Ethridge, F.G., 1994. Origin, evolution and morphology of fluvial valley. In: Dalrymple, R.W., Boyd, R.J., Zaitlin, B.A. (Eds.), Incised Valley Systems: Origin and Sedimentary Sequences. Soc. Sediment. Geol. Spec. Publ., vol. 51. SEPM, Tulsa, pp. 11–27.

SHOM, 1993. Courants de marée de la côte ouest de France: de Saint Nazaire à Royan. SHOM, Paris. 22 pp.

SHOM, 2003. Annuaire des marées: Ports de France. SHOM, Paris. 192 pp.

Sibuet, J.-C., Monti, S., Pautot, G., 1994. New bathymetric Map of the Bay of Biscay. Comptes Rendus de l'Académie des Sciences 318, 615–625.

Suter, J.R., Berryhill, H.L., Penland, S., 1987. Late quaternary sea-level fluctuation and depositional sequences, southwest Louisiana continental shelf. In: Nummedal, D., Pilkey, O.H., Howard, J.D. (Eds.), Sea-level Fluctuations and Coastal Evolution. Soc. Sediment. Geol. Spec. Publ., vol. 41. SEPM, Tulsa, pp. 199–219.

Swift, D.J.P., 1968. Coastal erosion and transgressive stratigraphy. Journal of Geology 76, 444–456.

Swift, D.J.P., Moir, R., Freeland, G.L., 1980. Quaternary rivers on the New Jersey shelf: relation of seafloor to buried valleys. Geology 8, 276–280.

Talling, P.J., 1998. How and where do incised valleys form if sea level remains above the shelf edge? Geology 26 (1), 87–90.

Tesson, M., 1973. Aspects dynamiques de la sédimentation dans la baie de Marennes-Oléron (France). Thèse, Univ. Bordeaux I, Bordeaux.

Van Vliet-Lanoë, B., Bonnet, S., Hallegouët, B., Laurent, M., 1997. Néotectonic and seismic activity in the armorican and cornubian massif: regional stress field with glacio-isostatic influence? Journal of Geodynamics 24 (1–4), 219–239.

Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M., Vail, P.R., Sarg, J.F., Loutit, T.S., Hardenbol, J., 1988. An overview of the fundamentals of sequence stratigraphy and key definitions. In: Wilgus, C.K., et al. (Eds.), Sea-Level Changes: An Integrated Approach. Soc. Sediment. Geol. Spec. Publ., vol. 42. SEPM, Tulsa, pp. 39–45.

Van Wagoner, J.C., Mitchum, R.M., Campion, K.M., Rahmanian, V.D., 1990. Siliclastic sequence stratigraphy in welkl logs, cores and outcrops. American Association of Petroleum Geologist Methods in Exploration Series 7 (55 pp.).

Walker, R.G., 1992. Facies, facies models and modern stratigraphic concepts. In: Walker, R.G., James, N.P. (Eds.), Facies Models. Geological Association of Canada, St John's, pp. 1–14.

Weber, N., Chaumillon, E., Tesson, M., 2003. Variation of Quaternary stratigraphic pattern along an incised valley fill, revealed by high resolution seismic profiling: the Paleo-Charente River (French Atlantic coast). 2003 AAPG Annual Convention, Salt Lack City, Vol., p. A178.

Wescott, W.A., 1993. Geomorphic thresholds and complex response of fluvial systems—some implications for sequence stratigraphy. Am. Assoc. Pet. Geol. Bull. 77 (7), 1208–1218.

Wood, L.J., Ethridge, F.G., Schumm, S.A., 1993. The effects of rate of base-level fluctuation on coastal-plain, shelf and slope depositional systems: an experimental approach. In: Posamentier, H.W., Summerhayes, C.P., Haq, B.U., Allen, G.P. (Eds.), Sequence Stratigraphy and Facies Associations. Int. Assoc. Sediment. Spec. Publ., vol. 18. IAS, pp. 43–53.

Zaitlin, B.A., Dalrymple, R.W., Boyd, R., 1994. The stratigraphic organisation of incised valley systems associated with relative sea-level change. In: Dalrymple, R.W., Boyd, R.J., Zaitlin, B.A. (Eds.), Incised Valley Systems: Origin and Sedimentary Sequences. Soc. Sediment. Geol. Spec. Publ., vol. 51. SEPM, Tulsa, pp. 45–60.