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Historical shifts of the Rhone River and catastrophic flood events revealed by multi-proxy analysis of the Rhone prodeltaic sediments (Gulf of Lions, NW Mediterranean)

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1. The Rhone deltaic system: an historical archive of environmental and anthropogenic events

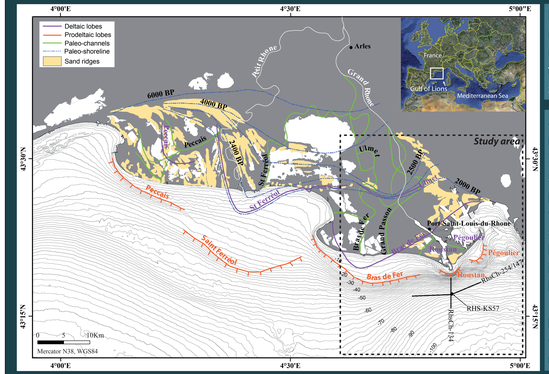


Fig. 1: Detailed morphology of the Rhone subaqueous delta and main onshore morpho-sedimentary features.

Rhone is one of the main river of Western Mediterranean Sea, and is an important source of freshwater and sediment (Table 1).

After the end of Last Glacial Maximum sea level drop (ca. 20 kyr ago), individual lobes accompanied the retreat path of the Rhone during sea-level rise. The late Holocene sediments are accumulated along the coastal zone, in the form of prodeltaic lobes (Berné et al., 2007) (Fig. 1), shifting eastward of the Rhone distributary channels, since the highstand phase (ca. 6kyr BP).

During the modern period, most of the river flow was delivered through the Bras de Fer, Pégoulier and Roustan distributary channels, which evolved under natural and human influences. The prodeltas associated to these distributaries offer very high sedimentation rates (> few cm s^{-1}) allowing the formation of expanded successions documenting extreme climate events at historical scale time.

Length (km)	Basin Area (km^2)	Water discharge ($m^3 s^{-1}$)	Sediment load ($t yr^{-1}$)	Tidal range (m)	Control
812	97 800	1 701	$7.4.10^6$	0.3	Wave

Table 1: The main characteristics of the Rhone River and delta.

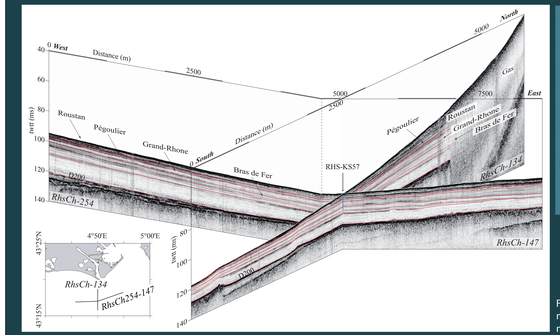
We focus on the last 4 centuries studying a core located on the recentmost Rhone prodeltaic lobe (RHS-KS57, Fig. 1).
This work represents the first attempt of paleo-environmental reconstruction of the subaqueous Rhone delta in the aim of:
1) establishing a precise stratigraphy of Holocene deposits;
2) tracing the extreme events (floods) and linking them to historical climate changes.

2. Material and methods

The 7.71 m piston core RHS-KS57, retrieved on the modern Roustan prodeltaic lobe at 79 m water depth during the RHOSOS cruise (R/V Le Suroît, 2008) has been used for a multiproxy paleo-environmental reconstruction, using:

(1) **microfossil assemblages** (ostracods and benthic foraminifera)
(2) **sedimentological proxies** (lithology, granulometry)
(3) **geochemical proxies** (^{137}Cs, Pb isotope, Organic Carbon)

3. Seismic- and chrono-stratigraphy



The seismic stratigraphy at the scale of the Roustan prodelta allows identifying several prograding units thicken landward (Fig. 2). They correspond to the distal prodeltaic muds belonging to the Bras de Fer, Grand Rhone, Pégoulier, and Roustan lobes (see position in Fig. 1).

Fig. 2: Seismic sections (Chirp) across the modern Roustan prodelta illustrating the main prograding units.

The core age model is based on 5 tie points determined on short-lived radionuclides (^{137}Cs), on isotopic Pb ratio ($^{206}Pb/^{207}Pb$) and on ^{14}C date.

Chronological tie points and sedimentation rates of the core RHS-KS57

Depth (cm)	Year (AD)	Proxy	Sedimentation rate ($cm\ yr^{-1}$)
0	2008	----	3.18
70	1986 (Tchernobyl accident)	^{137}Cs	1.52
105	1963 (Maximum atmospheric production)	^{137}Cs	4.1
146	1953 (1st year of atmospheric releases)	^{137}Cs	2.17
370	1850 (Beginning of the Indutsrial Revolution)	$^{206}Pb/^{207}Pb$	1.56
657	1671	^{14}C	
771	1597	----	

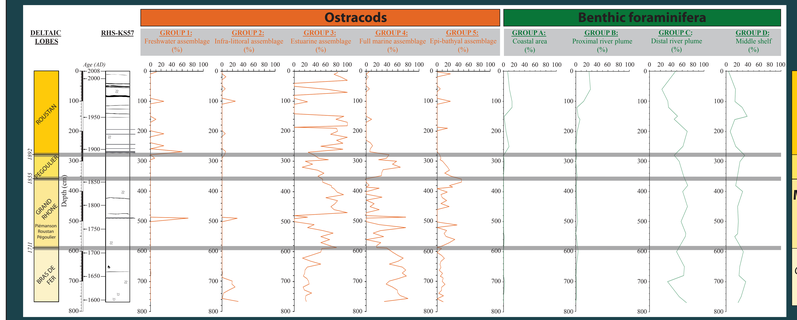
Rhone delta lobe shifts for the last four centuries.

Key dates of Rhone delta modern evolution

Deltaic lobes	Dates
ROUSTAN	1892 - Present day
Anthropogenic shift	
PEGOULIER	1855 - 1892
Anthropogenic shift	
GRAND RHONE (Piémanson, Roustan, Pégoulier)	1711 - 1852
Natural shift (floods)	
BRAS DE FER	1586 - 1711

4. Results & Conclusions

(1) Natural and man-induced shifts of the Rhone distributaries



Strong river influence
Loxoconcha spp. (ostr.)
Candona spp. (ostr.)
Nonionella turgida (foram.)
Quinqueloculina lata (foram.)

Low river influence

Moderate river influence
Loxoconcha spp. (ostr.)
Cassidulina carinata (foram.)
Valvulineria bradyana (foram.)

Low river influence
Cytherapteron rotundatum (ostr.)
Argilloecia sp. (ostr.)
Hyalinea balthica (foram.)

Fig. 3: Vertical distribution of ostracods and benthic foraminifera groups in the core RHS-KS57.

Each group of ostracods and benthic foraminifera (Fig. 3) is composed by species with similar ecological requirements (amount of dissolved O_2, organic matter supplies, salinity) and/or similar modern geographic and bathymetric distribution.
Four different intervals have been identified thanks to ostracods and foraminifera assemblages. They reflect:
1) the different position of distributary channels (*i.e.* distal *vs* proximal source of sediments and continental freshwater, Fig. 1);
2) the impact of large flloods on prodelta sedimentation (see below).

(2) The imprint of extreme floods

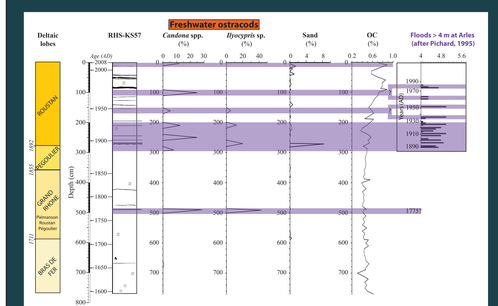


Fig. 4: Flood deposits identified thanks to freshwater ostracods, sediment grain-size and Organic Carbon content.

The punctual occurence of freshwater ostracods correlates with increases of grain-size and/or OC content (Fig. 4).
Freshwater ostracods are excellent markers for tracing floods since they are transported toward the sea within the river plume during extreme events.

The floods recorded in the core RHS-KS57 match well the events documented in the historical archives (Pichard, 1995).
This study demonstrates that the prodelta distal deposits well preserve the signature of large floods since they are prevented of coastal erosion.

Sediment plume of the Rhone after an exceptional flood (2003). Notice the position of the core under the influence of the river plume (Source: NASA MODIS).

References

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Pichard, G., 1995. Les crues sur le bas-Rhône de 1500 à nos jours. Pour une histoire hydroclimatique. Méditerranée, 3-4: 105-116.