Marine Geology 338 (2013) 17–29

Contents lists available at SciVerse ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margeo

High-resolution multiproxy records of sedimentological changes induced by dams in the Sept-Îles area (Gulf of St. Lawrence, Canada)

Ursule Boyer-Villemaire [a,b,*], Guillaume St-Onge [a], Pascal Bernatchez [b], Patrick Lajeunesse [c], Jacques Labrie [a]

[a] Canada Research Chair in Marine Geology, Institut des sciences de la mer de Rimouski (ISMER) & Centre de recherche GEOTOP, Université du Québec à Rimouski, 310, Allée des Ursulines, Rimouski, Québec, Canada G5L 3A1

[b] Chaire de recherche du Québec en géoscience côtière, Centre d'études nordiques & Département de biologie, chimie et géographie, Université du Québec à Rimouski, 300, Allée des Ursulines, Rimouski, Québec, Canada G5L 3A1

[c] Centre d'études nordiques & Département de géographie, Université Laval, Québec, Québec, Canada G1V 0A6

ARTICLE INFO

Article history:
Received 6 April 2012
Received in revised form 23 November 2012
Accepted 28 November 2012
Available online 11 December 2012

Communicated by D.J.W. Piper

Keywords:
land-use change
climate change
marine sedimentation
river damming
spectral analysis
Gulf of St. Lawrence
Sainte-Marguerite River
Moisie River

ABSTRACT

A multiproxy approach was performed on two sediment box cores sampled in the NW Gulf of St. Lawrence in order to better understand the impacts of recent climatic or land-use changes on the sedimentary regime in the proximal offshore zone. Multibeam and seismic surveys allowed for the careful selection of coring sites. The chronology of the cores was established by ^{210}Pb measurements and validated with coinciding historical weather events recorded in both cores, confirming that the sediments are recent (last 370 years). The lithological variations in the cores were quantified using 1) stratigraphic markers and grain size measurements, 2) high-resolution X-ray micro-fluorescence (XRF), and 3) physical and magnetic tracers. The grain size measurements allowed the identification of a major flood around AD 1844 ± 4 years, whereas a drastic decrease in variations and in the median grain size (d50) occurred around AD ~1900, highlighting the offshore impact of the SM1 dam construction on the Sainte-Marguerite River in the early 1900s. Sedimentological variations have been investigated by wavelet analysis using XRF data and the sharp disappearance of high frequencies (<16 year periods) around AD 1900 in the core facing the dammed river (Sainte-Marguerite River), but not in the reference core, also provides evidence of dam influence on the proximal offshore zone sedimentary regime. Indicators are proposed for a posteriori environmental impact assessment of dams.

1. Introduction

Impacts of dam construction on sediment fluxes and carbon cycling have been internationally recognized (Bates et al., 2008) and changes in flow regime and variations in the composition of suspended material have been documented in many major fluvial systems (e.g., Meybeck and Vörösmarty, 2005; Syvitski et al., 2005). The main challenge in studying sedimentary dam impacts is to disentangle the dam-induced sedimentological variations from the natural sedimentological background. In the fluvial environment, it has been addressed through the analysis of sedimentary series in order to establish the before/after threshold in the sedimentary regime and thus document the dam-induced impacts (Hart and Long, 1990; Klaver et al., 2007; Wang et al., 2009). Moreover, recent studies have demonstrated the effectiveness of wavelet analysis to document cyclical variations of geophysical processes over time (e.g., Kumar and Foufoula-Georgiou, 1997; Torrence and Compo, 1998). Similarly, other wavelet analysis studies have successfully combined classical sedimentological methods with other very high-resolution methods, such as the 100 μm downcore resolution afforded by X-ray micro-fluorescence (XRF) (Croudace et al., 2006; Thomson et al., 2006; Guyard et al., 2007), to decipher anthropogenic and natural influences (Kalicki et al., 2008), at the inter-annual- to decadal-scales. However, in the proximal offshore zone (here: from the low tide breaker line extending to the seaward line of fluvial influence), identifying a simple fluvial-induced threshold might be hazardous as it could also be induced by marine drivers. To overcome this, an innovative approach would be the combination of high-resolution proxies and a comparative approach. For example, in the coastal and proximal offshore open water environments, the analysis of well-dated (e.g., ^{210}Pb and ^{137}Cs) and undisturbed sediments revealed the possibility to uncover cumulative influence of other terrestrial human-induced changes such as deforestation, intensive agriculture and industrial and urban development, and impacts to the estuarine or near-shore sedimentary regime (e.g., Chagué-Goff et al., 2000; Cundy et al., 2003; Huguet et al., 2007). However, distinguishing the impacts in marine sediments of pre-industrial hydro-climatic changes from those of dam construction on the sedimentary regime is seldom done. Moreover, a comparative approach with a reference core

* Corresponding author at: Département de chimie, biologie et géographie, Université du Québec à Rimouski, 300, Allée des Ursulines, C.P. 3300, succ. A, Rimouski, Québec, Canada G5L 3A1. Tel.: +1 418 723 1986x1364; fax: +1 418 724 1525.
E-mail address: ursule.boyer-villemaire@uqar.qc.ca (U. Boyer-Villemaire).

0025-3227/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.margeo.2012.11.012

collected in the same local environment (a few km apart), but not submitted to the dammed river influence, should allow to assess local natural (fluvial and marine) variations and attribute certain variations or threshold to the exclusive influence of the dammed river catchment.

In this context, we hypothesize that the following methodological combination could highlight the dam-induced sedimentological variations from the natural (fluvial-marine) sedimentological background: the comparison of two undisturbed and well-dated high-resolution sedimentary proxies of a few centuries sampled from the same local region, but under different sedimentary regimes: 1) a reference core from the proximal offshore area under the influence of a natural river mouth and 2) a sediment core from the proximal offshore area under the influence of a dammed river.

The Sept-Iles area, NW Gulf of St. Lawrence, Eastern Canada (Fig. 1), is ideal to test our hypothesis as it holds two rivers under the same hydro-climatic regime, but one is a natural river (Moisie River) and the other (Sainte-Marguerite River) was recently impacted by the construction of dams starting in the early 1900s. Moreover, the rivers are large, they stream in abundant post-glacial material and the offshore sedimentation rates are quite high, from 0.14 to 0.70 cm/yr (Smith and Schafer, 1999; Lajeunesse et al., 2007; Normandeau, 2011). In this study, we describe and discuss the natural variability of the sedimentary regime for the last three centuries in relation to hydro-climatic variations and the impact of dam construction in the proximal offshore environment of the Sainte-Marguerite River.

2. Regional setting

2.1. Geological and geomorphic setting

At the convergence of the Appalachian and Grenville orogens in the Eastern Canada, the Gulf of St. Lawrence is a semi-enclosed sea of 226,000 km^2 composed of a shallow-submerged Paleozoic lowlands incised by the submarine u-shaped Laurentian Channel (Piper et al., 1990). Receiving the brackish waters of the St. Lawrence River Estuary

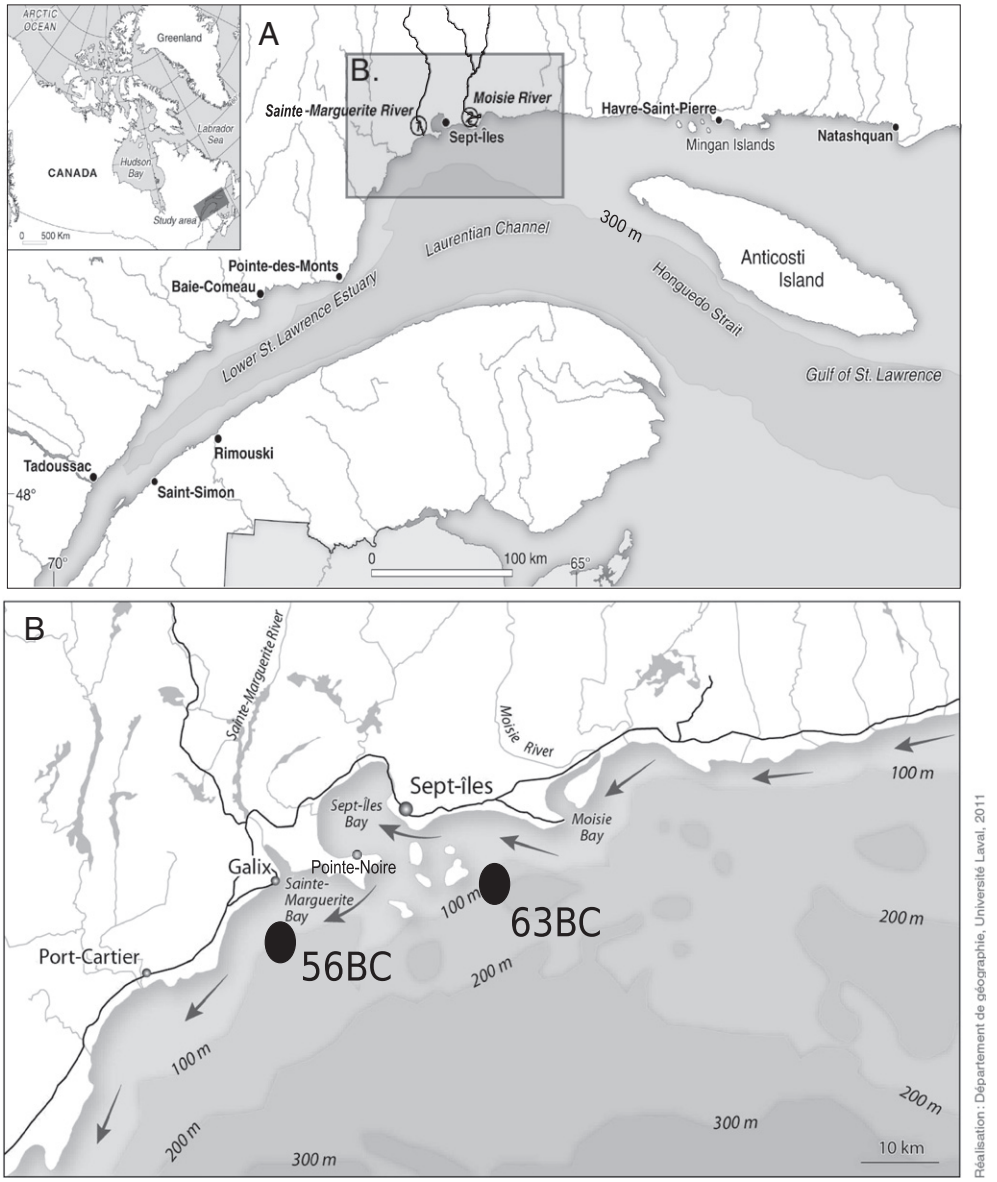

Fig. 1. The Gulf of St. Lawrence (A) and the Sept-Îles area (B), showing the sampling location of cores 56BC and 63BC. (1) Sainte-Marguerite River and (2) Moisie River. Also illustrated are the localities mentioned in the text. Solid black arrows represent the primary littoral drift directions. Bathymetry is represented by gray areas.