Marine Geology 337 (2013) 20–34

Contents lists available at SciVerse ScienceDirect

Marine Geology

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

Annual record of particle fluxes, geochemistry and diatoms in Effingham Inlet, British Columbia, Canada, and the impact of the 1999 La Niña event

Alice S. Chang [a,*], Miriam A. Bertram [b,1], Tara Ivanochko [c], Stephen E. Calvert [c], Audrey Dallimore [d], Richard E. Thomson [e]

[a] Department of Earth Sciences, Carleton University, Ottawa-Carleton Geoscience Centre, 1125 Colonel By Drive, Ottawa, Ontario, Canada K1S 5B6
[b] Pacific Marine Environmental Laboratory, NOAA/R/PMEL, 7600 Sand Point Way NE, Seattle, WA 98115, USA
[c] Department of Earth and Ocean Sciences, University of British Columbia, 6339 Stores Road, Vancouver, British Columbia, Canada V6T 1Z4
[d] Geological Survey of Canada—Pacific, PO Box 6000, Sidney, British Columbia, Canada V8L 4B2
[e] Department of Fisheries and Oceans, Ocean Sciences Division, Institute of Ocean Sciences, PO Box 6000, Sidney, British Columbia, Canada V8L 4B2

ARTICLE INFO

Article history:
Received 5 February 2012
Received in revised form 21 October 2012
Accepted 14 January 2013
Available online 4 February 2013

Communicated by G.J. de Lange

Keywords:
particle flux
geochemistry
diatoms
sediment traps
La Niña
Effingham Inlet
northeast Pacific Ocean

ABSTRACT

Sediment traps were deployed inside the anoxic inner basin of Effingham Inlet and at the oxygenated mouth of the inlet from May 1999 to September 2000 in a pilot study to determine the annual depositional cycle and impact of the 1999 La Niña event within a western Canadian inlet facing the open Pacific Ocean. Total mass flux, geochemical parameters (carbon, nitrogen, opal, major and minor element contents, and stable isotope ratios) and diatom assemblages were determined and compared with meteorological and oceanographic data. Deposition was seasonal, with coarser grained terrestrial components and benthic diatoms settling in the autumn and winter, coincident with the rainy season. Marine sedimentary components and abundant pelagic diatoms were coincident with coastal upwelling in the spring and summer. Despite the seasonal differences in deposition, the typical temperate-zone *Thalassiosira–Skeletonema–Chaetoceros* bloom succession was muted. A July 1999 total mass flux peak and an increase in biogenous components coincided with a rare bottom-water oxygen renewal event in the inlet. Likewise, there were cooler-than-average sea surface temperatures (SSTs) just outside the inlet, and unusually high abundances of a previously undescribed cool-water marine diatom (*Fragilariopsis pacifica* sp. nov.) within the inlet. Each of these occurrences likely reflects a response to the strong La Niña that followed the year after the strongest-ever recorded El Niño event of 1997–1998. By the autumn of 1999, SSTs had returned to average, and *F. pacifica* had all but disappeared from the remaining trap record, indicating that oceanographic conditions had returned to normal. Oxygenation events were not witnessed in the inlet in the years before or after 1999, suggesting that a rare oceanographic and climatic event was captured by this sediment trap time series. The data from this record can therefore be used as a benchmark for identifying anomalous environmental conditions on this coast.

1. Introduction

Annually laminated diatomaceous sediments from anoxic and suboxic coastal basins such as Saanich Inlet (southeastern Vancouver Island, British Columbia), Santa Barbara Basin (offshore southern California) and the basins in the central Gulf of California have long been used as high-resolution paleoenvironmental records from which the formation of varves, past climate changes and/or anomalous environmental events have been assessed (e.g., Calvert, 1966; Schimmelmann et al., 1992; McQuoid and Hobson, 1997; Dean and Kemp, 2004). The discovery of well preserved annual diatomaceous laminae in Effingham Inlet, a glacially excavated anoxic fjord on the southwestern coast of Vancouver Island in the northeast Pacific (Fig. 1), has been the focus of recent attention (Hurtgen et al., 1999; Chang et al., 2003; Ingall et al., 2005; Hay et al., 2007; Dallimore et al., 2008; Ivanochko et al., 2008). Close examination of laminated sediment records reveals that although the alternations of dark terrigenous and light diatomaceous laminae are repetitive (i.e., annual), there are variations in the composition and thickness of laminae that most likely result from seasonal to interannual variability in depositional conditions and therefore changes in the local and/or regional environment (Brodie and Kemp, 1994; Kemp, 1995; Molina-Cruz et al., 2002; Chang and Patterson, 2005, 2007). To validate interpretations of depositional processes and to

* Corresponding author at: Department of Forest and Conservation Sciences, University of British Columbia, 3041-2424 Main Mall, Vancouver, British Columbia, Canada V6T 1Z4. Tel.: +1 604 822 3047; fax: +1 604 822 9102.
E-mail addresses: alice.chang@ubc.ca (A.S. Chang), mbertram@ocean.washington.edu (M.A. Bertram), tivanoch@eos.ubc.ca (T. Ivanochko), calvert@eos.ubc.ca (S.E. Calvert), audrey.dallimore@nrcan.gc.ca (A. Dallimore), Richard.Thomson@dfo-mpo.gc.ca (R.E. Thomson).
[1] Current address: Program on Climate Change, University of Washington, Box 355351, Seattle, WA 98195-7940, USA.

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http://dx.doi.org/10.1016/j.margeo.2013.01.003

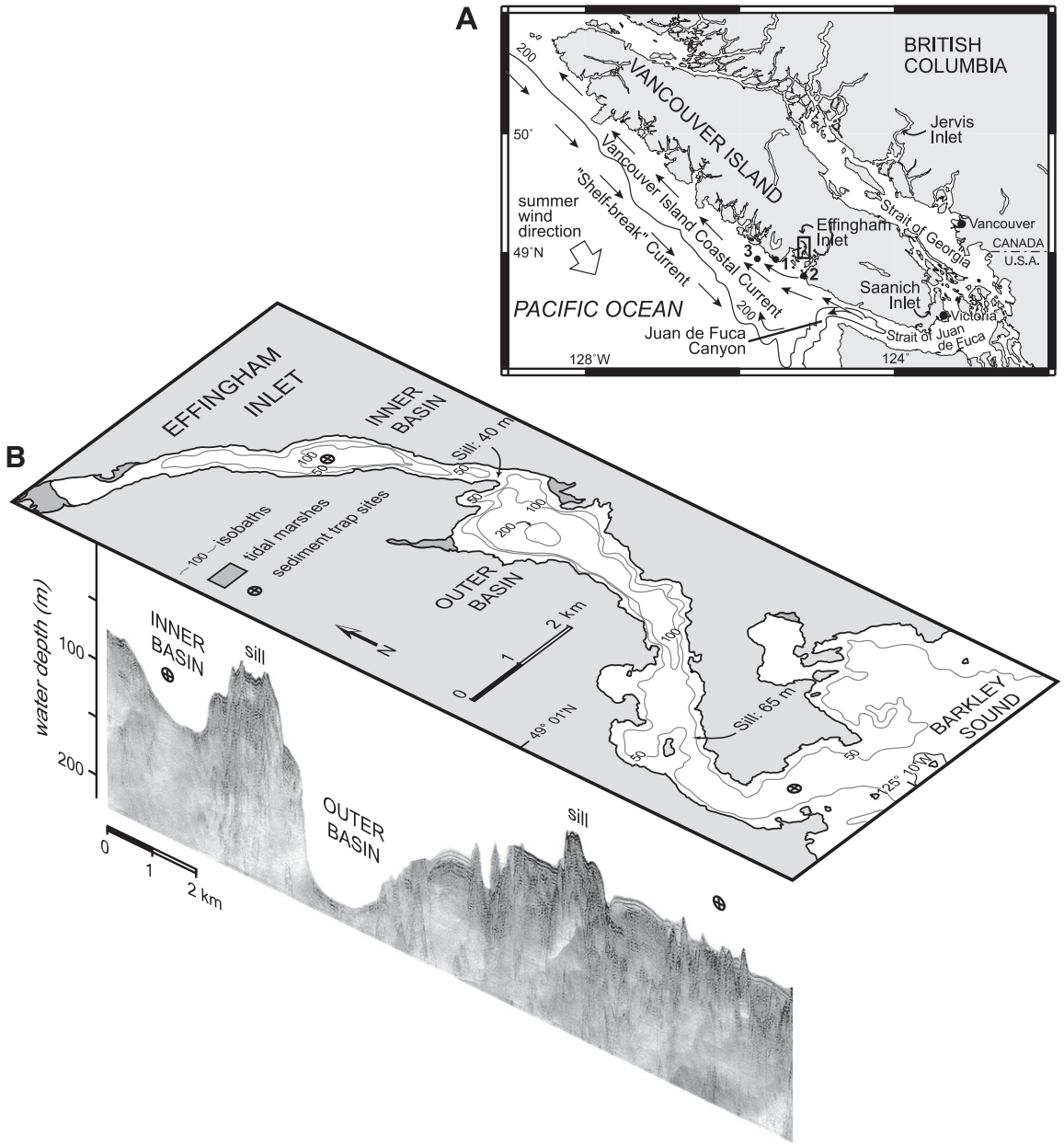

Fig. 1. Study area. (A) Regional map showing locations discussed in this study, summer surface currents, and meteorological stations Amphitrite Point (1), Cape Beale (2), and Meteorological Buoy 46206 on La Pérouse Bank (3). The 200-m isobath is the approximate location of the shelf break. (B) Detailed map of Effingham Inlet, seismic profile generated from a 3.5 kHz sub-bottom sounder traverse, and sediment trap sites.

understand how laminae are formed, in situ time series observations are required. This is achieved via the determination of modern particle settling fluxes and composition through the use of time-series particle traps, and comparison of these data to the available instrumental environmental record (Sancetta and Calvert, 1988; Sancetta, 1989; Waite et al., 1992; Lange et al., 1997).

In this paper we present a comprehensive time-series record of the geochemical and microfloral composition of settling particles from a 16-month sediment trap deployment in Effingham Inlet from May 1999 to September 2000. Coeval environmental records from regional meteorological stations (Fig. 1A) are compared to the flux records to identify physical processes contributing to the depositional patterns observed. This is the first and only sediment trap study in Effingham Inlet, and is also the first study to use sediment traps in a western Canadian fjord directly connected to the Pacific Ocean. Effingham Inlet opens to the Pacific via Barkley Sound and is minimally affected or diluted by major river systems, such as the Fraser River (near Vancouver), or estuarine straits, such as the Strait of Georgia (Fig. 1A). The inlet is thus ideally located to capture relatively unfiltered records of open ocean events in the neighboring eastern Pacific.

Although the deployment period missed the strongest recorded 1997–1998 El Niño event and the transition into the equally strong La Niña event, it does cover the end of the La Niña interval in 1999 and the transition into normal climatological conditions along the British Columbia coast, complementing the work of Harris et al. (2009). Since our experiment duration was just over one year, we do not have long-term, "normal" conditions recorded. However, to maximize on the limited material available, the short time interval covered and the paucity of time series data in the region, a wide suite of pertinent proxies was analyzed such that the data presented here can be used as a baseline for assessing diatom productivity and