Marine Geology 380 (2016) 163–173

Contents lists available at ScienceDirect

Marine Geology

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

Sedimentation, stratigraphy and physical properties of sediment on the Juan de Fuca Ridge

K.M. Costa [a,b,*], J.F. McManus [a,b], B. Boulahanis [a,b], S.M. Carbotte [a], G. Winckler [a,b], P.J. Huybers [c], C.H. Langmuir [c]

[a] Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA
[b] Department of Earth and Environmental Sciences, Columbia University, New York, NY 10027, USA
[c] Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA

ARTICLE INFO

Article history:
Received 7 May 2016
Received in revised form 1 August 2016
Accepted 4 August 2016
Available online 06 August 2016

Keywords:
Juan de Fuca Ridge
Sedimentation rates
Sediment density
Oxygen isotope stratigraphy

ABSTRACT

Sedimentation near mid-ocean ridges may differ from pelagic sedimentation due to the influence of the ridges' rough topography on sediment deposition and transport. This study explores whether the near-ridge environment responds to glacial-interglacial changes in climate and oceanography. New benthic $\delta^{18}O$, radiocarbon, multi-sensor track, and physical property (sedimentation rates, density, magnetic susceptibility) data for seven cores on the Juan de Fuca Ridge provide multiple records covering the past 700,000 years of oceanographic history of the Northeast Pacific Ocean. Systematic variations in sediment density and coarse fraction correspond to glacial-interglacial cycles identified in benthic $\delta^{18}O$, and these observations may provide a framework for mapping the $\delta^{18}O$ chronostratigraphy via sediment density to other locations on the Juan de Fuca Ridge and beyond. Sedimentation rates generally range from 0.5 to 3 cm/kyr, with background pelagic sedimentation rates close to 1 cm/kyr. Variability in sedimentation rates close to the ridge likely reflects remobilization of sediment caused by the high relief of the ridge bathymetry. Sedimentation patterns primarily reflect divergence of sedimentation rates with distance from the ridge axis and glacial-interglacial variation in sedimentation that may reflect carbonate preservation cycles as well as preferential remobilization of fine material.

1. Introduction

Marine sediments are a storehouse of the geochemical, biological, and physical changes in the ocean over thousands to millions of years. Their archival utility is predicated on slowly settling sediment blanketing the submarine landscape to abyssal flatness, but rough topographic features like hills, seamounts, and ridges can distort flow fields and depositional dynamics of sediment on the seafloor (Dubois and Mitchell, 2012; Johnson and Johnson, 1970; Mitchell and Huthnance, 2013; Turnewitsch et al., 2013; von Stackelberg et al., 1979). Uneven topography can alternately deflect, accelerate, and decelerate bottom currents, generating a heterogeneous depositional environment over a wide range of spatial and temporal scales (Turnewitsch et al., 2013). Extensive two-dimensional topographic features, such as mid-ocean ridges and submarine canyons, exhibit prominent sediment mobilization and transport from bathymetric highs to lows, both by currents and by downslope gravitational flows. Acoustic profiling characterizes sediment distribution, thickness, and depositional processes in the modern near-ridge environments of the Mid-Atlantic Ridge and the East Pacific Rise (Ewing et al., 1964; Hauschild et al., 2003; Lister, 1976; Marks, 1981; Mitchell et al., 1998; Ruddiman, 1972), but how these depositional environments respond to glacial-interglacial variability is poorly constrained. The unique geochemical and biological microcosm of a mid-ocean ridge motivates investigation into the integrity of the sediment medium to record the evolution of the ridge system over time.

Ridge-influenced sedimentary regimes can be recorded in the physical properties of sediments (Turnewitsch et al., 2013), such as accumulation rate, density, and magnetic susceptibility. These physical properties respond to changes in the porosity, the density and geochemical composition of the grains (e.g., calcium carbonate, terrigenous silicate, hydrothermal metals), and the grain size and shape (Breitzke, 2006). Variability in the flow field geometry translates into lower sediment accumulation rates and coarser grains under fast flows and higher sediment accumulation rates and finer grains in more quiescent areas. These spatial patterns compound with temporal variability, such as glacial-interglacial cycles in carbonate preservation (Farrell and Prell, 1989), which can affect both the density and grain size of the sediment medium. This paper presents sedimentation rates, density, and magnetic susceptibility for a suite of seven cores covering almost 700,000 years of sedimentation on the Juan de Fuca Ridge. We aim to determine the major modes of sedimentation in the near-ridge environment and

* Corresponding author at: Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA.
E-mail address: kcosta@ldeo.columbia.edu (K.M. Costa).

http://dx.doi.org/10.1016/j.margeo.2016.08.003
0025-3227/

explore how they may have varied with climatic and oceanographic changes associated with glacial-interglacial cycles.

2. Study site & oceanography

The Juan de Fuca Ridge (JdFR) is located in the Northeast Pacific Ocean about 500 km off the coast of North America in the subpolar transition zone, where warm surface waters from the west wind drift diverge into the California Current, flowing south, and into the Alaskan Gyre, flowing north (Hickey, 1979). Bottom waters in the vicinity of the JdFR are composed of Pacific Deep Water (Macdonald et al., 2009) (Fig. 1), which constitutes the oldest and most corrosive deepwater in the modern ocean (Key et al., 2002; Kroopnick, 1985). Because corrosivity of deep Pacific waters leads to poor carbonate preservation (e.g., Karlin et al., 1992), paleoceanographic investigations into this region have been limited by low sedimentation rates and difficulties generating age models via foraminiferal stable isotope stratigraphy. Thus the relatively shallow sedimentary environment on the JdFR (<3000 m), which rises above the corrosive bottom waters, may provide important information about ocean circulation and chemistry in this understudied region.

The JdFR is an intermediate spreading ridge (56 mm/yr) that is characterized by extensive hydrothermal activity and hot spot volcanism (Karsten and Delaney, 1989; Massoth et al., 1994; Normark et al., 1983; Wilson, 1993). The Cleft Segment of the JdFR is located at the southern end of the ridge system, bounded by the Vance Segment to the north and the Blanco Fracture Zone to the south. The Cleft Segment is 55 km long and contains a modest axial rift that is 50–150 m deep and 2–4 km wide (Baker et al., 1989; Carbotte et al., 2006). Hydrothermal activity occurs within the rift valley both as diffuse venting, along the southern 18 km of the segment, and as discrete venting, via Pipe Organ, Monolith, and Fountain vents at the north end of the segment (Massoth et al., 1994). Outside the rift valley is a thinly sedimented axial plateau with low relief abyssal hills that extends approximately 16 km from the ridge axis and terminates in a 300 m scarp before continuing into regularly spaced, ridge-parallel crests and troughs further on the ridge flanks (Carbotte et al., 2008, 2006). Whereas the western flanks contain the preponderance of seamounts and hotspot activity (Davis and Karsten, 1986), the eastern flanks suffer from frequent turbidity current activity off the coast of North America (e.g., Goldfinger et al., 2012; Horn et al., 1971). Turbidity currents interrupt and sometimes erode hemipelagic sedimentation and interfere with sedimentological reconstructions of glacial-interglacial climate change, so that the spatial and temporal variability in sedimentation in this region is poorly constrained. To minimize the influence of turbidity currents, this study focuses on cores that were collected from the western flanks of the Cleft Segment on the SeaVOICE cruise (AT26-19) of the R/V Atlantis in September 2014 (Table 1).

During the cruise, over 50 m of sediment was collected on the JdFR flanks, in addition to basalt rock cores and high-resolution multi-beam sonar mapping. This paper focuses on the longest, stratigraphically-intact records of six piston cores (05PC, 09PC, 12PC, 20PC, 35PC, 38PC) and one “Big Bertha” gravity core (39BB). Bathymetric highs were targeted for coring sites to maximize carbonate preservation, and so cores were recovered from a limited depth range (2655–2794 m) along the crests of ridge-parallel abyssal hills. This coring strategy resulted in both ridge-perpendicular transects as well as ridge-parallel transects along basement isochrons, based on geomagnetic reversals

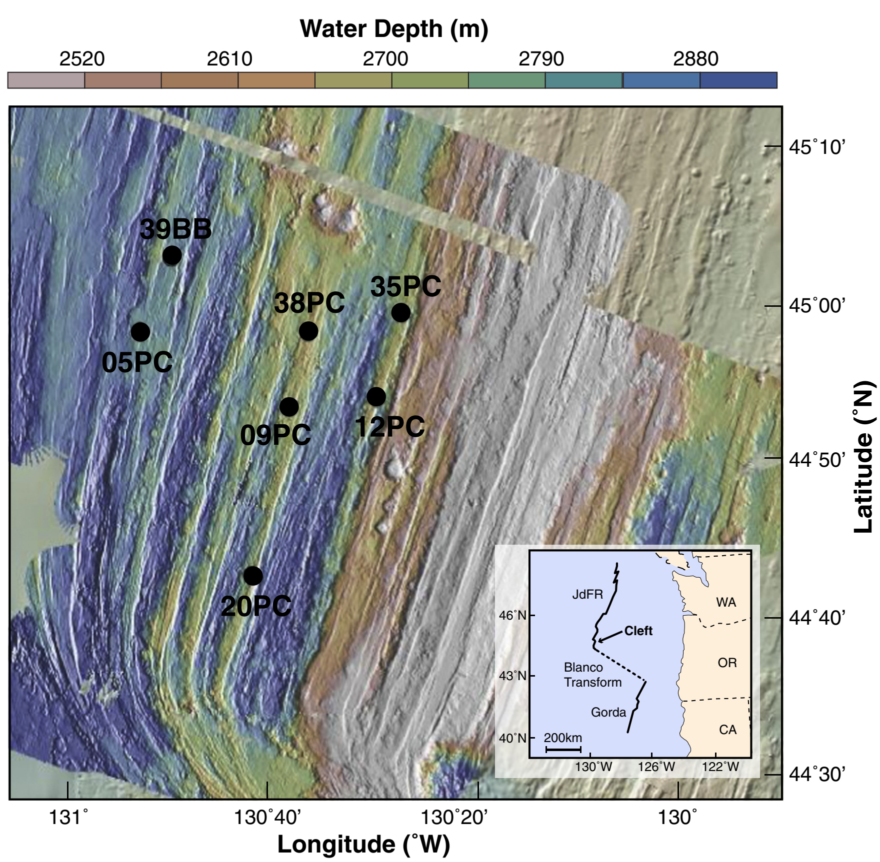

Fig. 1. Map of the study region. Location of the Cleft Segment of the Juan de Fuca Ridge relative to the North American coast. Bathymetric map of the Cleft Segment generated by shipboard multibeam data. The ridge can be identified as the NE-SW trending bathymetric high (in white). AT26-19 core locations on the western flanks of the ridge are shown with black circles, and locations are provided in Table 1. All cores were recovered from the crests of abyssal hills in order to obtain sediments with adequate carbonate preservation to generate age models. Cores 12PC and 35PC are both located next to the scarp that defines the boundary of the poorly sedimented axial plateau. (Inset) Location of the Cleft Segment of the Juan de Fuca Ridge relative to the North American coast.