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Interbedded Late Quaternary turbidites and contourites in Flemish Pass, off southeast Canada: Their recognition, origin and temporal variation

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ABSTRACT

The recognition of contourite and turbidite deposits in deep-marine sequences can be challenging, as deposits may show similar sedimentary characteristics. In Flemish Pass, a small, 1100 m deep, perched basin along the southeast Canadian continental margin, both types of deposits occur. Late Quaternary sediments include thin sand layers interbedded with hemipelagic muds. The distribution, age, sedimentary structures and petrology of these sands were used to distinguish between turbidite and contourite deposits, which were then characterized by detailed grain size distribution for understanding the conditions leading to deposition of each type. Seven sediment facies each with a distinctive grain size distribution were recognized. They are 1—transported contourites, 2—winnowed beds, 3—possible jökulhlaup deposits, 4—sandy turbidites, 5—muddy turbidites, 6—hemipelagic sediment and 7—turbidites from well-sorted materials. Sand packets comprised of several stacked turbidite sand beds, some with erosive contacts, were correlated from the margin to the basin floor, showing clear distal fining, and creating a small lobe. The temporal distribution of the sand beds indicates that most turbidites and contourites were deposited at stadial to interstadial transitions. This linkage may be related to variations in the oceanic circulation in Flemish Pass, which winnowed turbidites and may have triggered turbidity currents by moving sands into canyon heads.

1. Introduction

Turbidity currents are important agents for transporting sands of a wide grain size range into the deep water. Sediments deposited by turbidity currents may be subject to bottom current reworking, forming contourite deposits or winnowed sequences that may be recognized from sedimentary architecture interpreted from seismic-reflection profiles (e. g. Stow et al., 2002; Carter, 2007; Duarte and Viana, 2007). Nevertheless, in ancient successions there remains considerable uncertainty as to whether some sandstones are of turbidite or contourite origin. Some proposed criteria, such as the presence of tractional structures (Ito, 2002), are regarded by other authors as indicating normal turbidite deposition (Amy et al., 2005). Other criteria, such as intense bioturbation (Moraes et al., 2007), may be locally useful but are not of general applicability. In some settings, petrography is not of value in distinguishing contourites from turbidites (Shapiro et al., 2007). Grain size distribution (sortable silt) has been widely used in modern contourites systems to interpret variability in current strength (McCave et al., 1995; McCave, 2008).

Flemish Pass is a small, perched slope basin along the eastern Canadian continental margin (Fig. 1), through which the powerful Labrador Current flows southwards. Due to its bathymetric setting, turbidite sands derived from the outer continental shelf of the Grand Banks are trapped at ~1100 m water depth (Piper and Pereira, 1992) and can therefore be sampled more easily by piston cores than if these beds were deposited in the abyssal plains to the north and south of Flemish Pass. Seismic-reflection profiles show evidence for reworking of the seabed by the Labrador Current (Piper and Campbell, 2005).

The purpose of this paper is to use the Late Quaternary sand beds of Flemish Pass to evaluate how sand bed distribution, petrography and grain size can be used to distinguish turbidites from contourites. The temporal variation in these two sediment types is then related to changes in paleo-environmental conditions on stadial to interstadial timescales. Sand beds from Flemish Pass were studied within cores and correlated between cores. The sedimentological and petrographic characters and the distribution of the different sand beds in time and space were used to distinguish between turbidite and contourite deposits. Each type was characterized by a distinct grain size distribution. Their age and distribution were used to understand processes leading to the formation of each sediment type.

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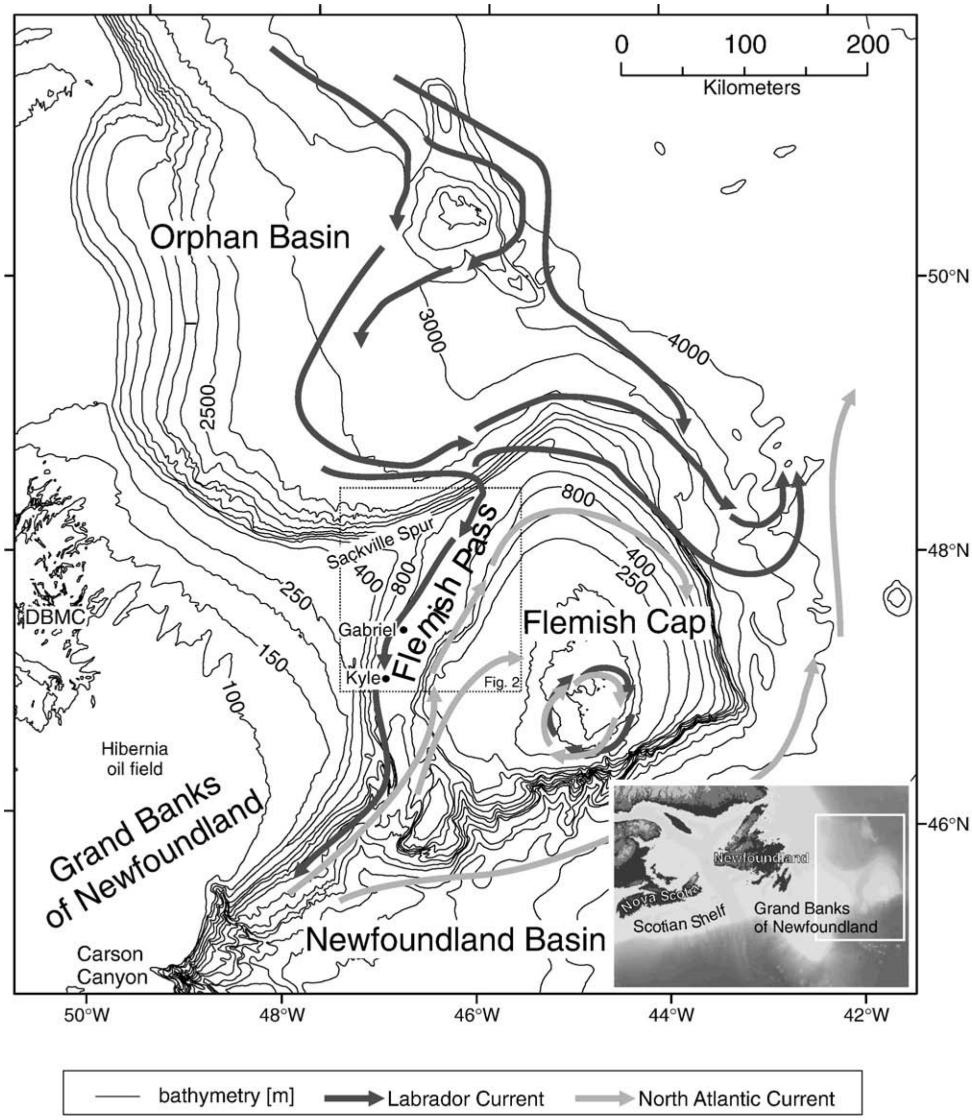

Fig. 1. Location map of Flemish Pass along the southeast Canadian continental margin. Black dots are exploration wells in Flemish Pass, DBMC = Downing Basin Moraine Complex (Huppertz and Piper, 2009). Ocean circulation (arrows) after Colbourne and Foote (2000).

2. Regional setting

2.1. Physiography

The southeastern Canadian continental margin includes three bathymetric basins seaward of the Grand Banks: Flemish Pass to the east, Orphan Basin to the northeast and the Newfoundland Basin to the southeast (Fig. 1). This margin was created during initial rifting of the North Atlantic in Cretaceous times and Flemish Pass is considered to be a failed rift (Grant, 1972; Foster and Robinson, 1993).

Flemish Pass is 1100 m deep and 50 km wide in its central part near the Kyle well (Fig. 1). The basin widens both northward and southward: in the north off Sackville Spur the basin is 80 km wide and in the south the basin reaches widths of more than 100 km before it drops off steeply into the Newfoundland Basin (Fig. 1). The depth of the shelf break on the Grand Banks deepens northward, from 200 m near the Kyle well to 450 m along Sackville Spur (Figs. 1 and 2), as a result of differential subsidence (King and Sonnichsen, 1999). Flemish Cap is a basement high east of Flemish Pass with a poorly defined shelf break at about 350 m bounding a 150 by 200 km plateau, which is 139 m deep at its shallowest point (Monahan and Macnab, 1974; King et al., 1985).

2.2. Geology of Flemish Pass

Flemish Pass has been gradually infilled from the Grand Banks slope with Mesozoic–Cenozoic fluvial-deltaic sequences that prograded eastwards (Foster and Robinson, 1993). Glacial ice crossed the Grand Banks at times in the Quaternary. During oxygen isotope stage (OIS) 2, ice covered only parts of the Grand Banks and likely terminated near the Downing Basin moraine complex (DBMC in Fig. 1) on the inner shelf (King et al., 2001; Huppertz and Piper, 2009). Some of the thick surficial sand deposits in the area of the Hibernia oil field have been interpreted as proglacial deposits (Fader and King, 1981).

The shallow Quaternary sedimentary sequence in Flemish Pass is dominated by hemipelagic and turbidite muds with few sedimentary structures preserved in cores (Piper and Pereira, 1992). Mass transport deposits (MTDs), interpreted from high resolution seismic profiles, are widespread in the shallow subsurface of central Flemish Pass (Piper and Campbell, 2005). Some sandy beds on a decimeter to meter scale are interbedded with the muds and have been interpreted as turbidites transported across the Grand Banks slope, with slope channels west of the Kyle and Gabriel wells being important input points (Piper and Pereira, 1992). Seaward of these slope channels are