SEDIMENT INSTABILITY IN ORPHAN BASIN, OFFSHORE EASTERN CANADA

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ABSTRACT
The Geological Survey of Canada (Atlantic) has an ongoing field and laboratory investigation of sediment properties in the upper few hundred metres of seabed in Orphan Basin, including high-resolution seismic profiling and geotechnical measurements in 10 m long piston cores. Much of the central part of the basin is underlain by a glacial trough-mouth fan seaward of Trinity Trough. The seabed south of the Trinity trough-mouth fan is underlain by mass-transport deposits, interbedded with terrigenous hemipelagic sediments, contourites, and overbank turbidites. Failure is widespread on the steep southern margin of the basin and has been evaluated by geotechnical measurements including triaxial shear testing in piston cores. The seabed is dissected by canyons that lead to erosional channels on the basin floor. These channels coalesce south of Orphan Knoll, where an erosional channel leads to a classic submarine fan north of Flemish Cap. Levee turbidites from this fan provide a record of the frequency of both landslide generated and ice-margin turbidity currents. The recurrence interval of slope sediment failures is also estimated from high-resolution seismic stratigraphy chronologically calibrated by piston cores.

RÉSUMÉ
La Commission Geologique du Canada avait une enquête courant des attributs de la sediment des premieres centaines de metres du fond de la mer dans l'Orphan Basin. Cette enquete contenu les profiles seismic d'haute-resolution et les measures geotechnique avec les noyaus de piston de 10m. La plupart de la bassine centrale avait un evantail glacial au dessous du fond de la mer a l'ouest de Trinity Trough. Au sud de Trinity Trough il y a des depots du transport massif au dessous du fond de la mer avec les sediments hemipelagique, les contourites, et les turbidites au dela de bord. L'echec des sediments est partout sur le marge au sud de la bassine et c'etait evaluer par les measures geotechnique. Le fond de la mer est sectionner par les canyons qui forment les canals erosional au fond de la bassine. Ces canals adjoignent au sud d'Orphan Knoll, ou un canal erosional resulte avec un evantail sous-marine au nord de Flemish Cap. Les turbidites levee qui resultent de cet evantail donnent un record de la frequence des flots turbids. L'intervalle de recurrence des echecs du sediment de la cote est estimer par la stratigraphe seismic d'haute-resolution qui est calibrer chronologique par les noyaus de piston.

1. INTRODUCTION

Orphan Basin is a 2000-3000 m deep part of the continental margin north of the Grand Banks of Newfoundland and west of the continental fragment of Orphan Knoll (Fig. 1). On its western side, Trinity Trough on the Northeast Newfoundland Shelf appears to have been a major source of Quaternary sediment (Hiscott and Aksu 1996). The steep continental slope leads to a more gentle continental rise at 2000-3000 m. Orphan Basin is bounded to the east by Orphan Knoll, but slopes more gently into deeper water both to the north of Orphan Knoll and through a 50 km wide pass between Orphan Knoll and Flemish Cap. Channels on the floor of Orphan Basin converge towards this pass and lead to the Labrador Basin.

The continental slope of Orphan Basin is swept by the Labrador Current and the deeper part of the basin is influenced by the Western Boundary Undercurrent. Both

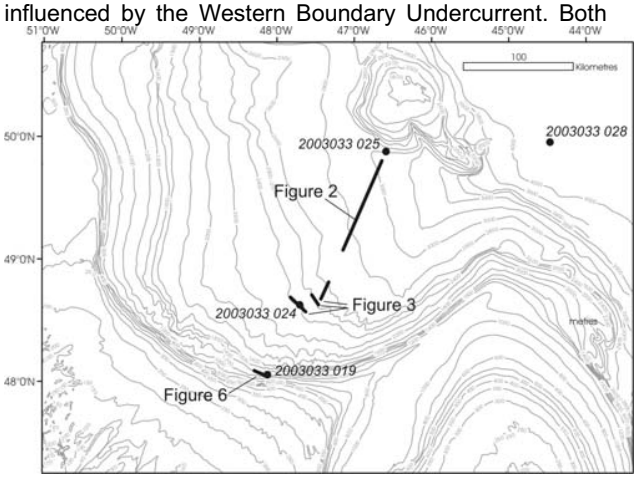

Figure 1- General map of Orphan Basin.

of these currents winnow surficial sediment (Carter 1979; Carter et al. 1979; Carter and Schafer 1983).

2. STRATIGRAPHY OF THE DEEP BASIN

In the deep part of Orphan Basin, the uppermost 100-200 ms consists of subparallel reflections returned by stratified sediments with thin interbedded acoustically incoherent packages interpreted as mass-transport deposits (Fig. 2). Mass-transport deposits (MTDs) become more abundant deeper in the stratigraphy and in the western part of the basin. Correlation with the dated long MD-95-2026 core (Hiscott et al. 2001) suggests that the upper more stratified unit dates from the mid Pleistocene and perhaps represents deposition in the past 0.5 Ma.

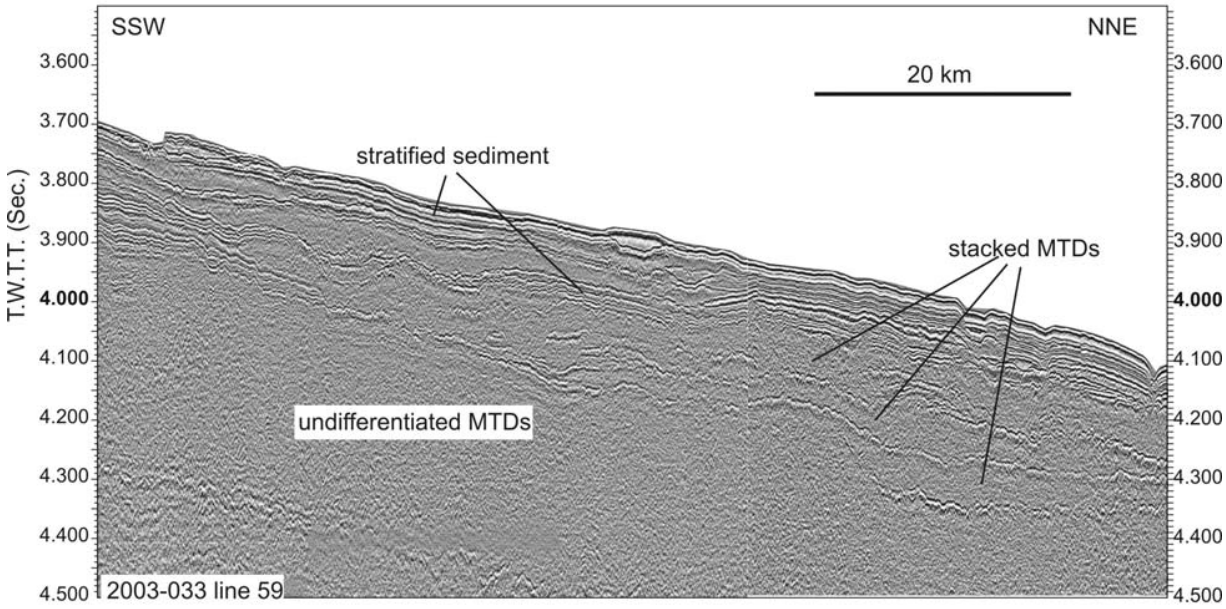

Figure 2- Seismic reflection profile on the floor of Orphan Basin showing stratified sediment unit overlying mass-transport deposit unit.

Shallow diapiric structures rise from the MTDs and penetrate surface stratified sediment (Fig. 3). Erosional channels cross the floor of the basin and have built low levees. Cores from the channels show a drape of hemipelagic sediment with thin turbidites overlying an erosional surface. Cores from the levees (e.g., core 24, Fig. 4) show a sand bed equivalent to the erosional horizon. This suggests that powerful turbidity currents essentially bypass the channels without depositing, but do deposit a little overbank material. Mud turbidites are found on the margin of Orphan Knoll tens of metres above the floor of Orphan Basin (core 25, Fig. 4) and are deposited seaward of the pass south of Orphan Knoll (core 28, Fig. 4). All cores have a correlatable succession of carbonate-rich Heinrich layers (picked out by high L colour values, Fig. 4) that allow the history of the basin over the last 30 000 years to be interpreted. Most sediment is deposited either from proglacial plumes or muddy turbidity currents, with hemipelagic sedimentation in the mid to late Holocene.

3. STRATIGRAPHY OF THE CONTINENTAL SLOPE

In the upper hundred milliseconds beneath the continental

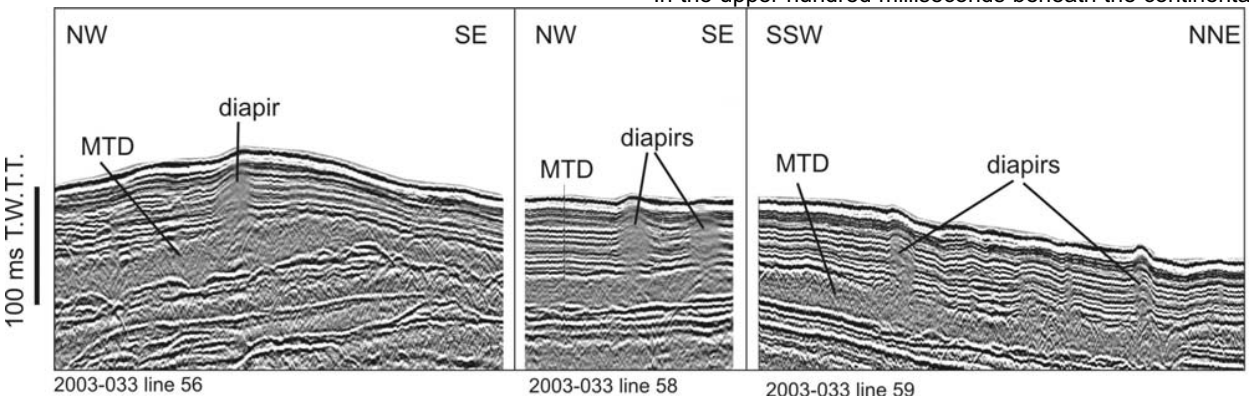

Figure 3- Diapiric structure associated with mass-transport deposits.

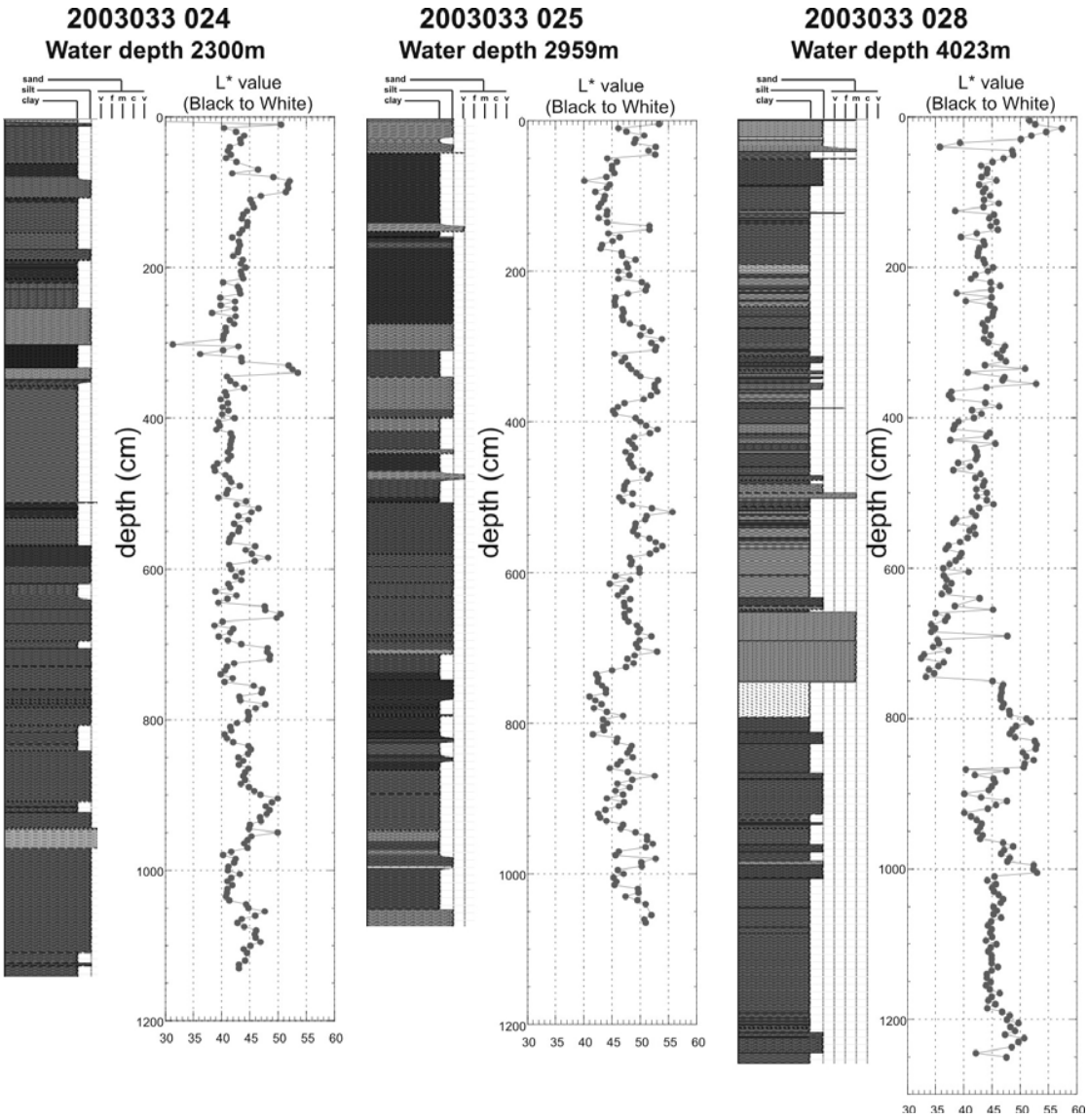

Figure 4- Down-core logs from Orphan Basin.

slope, stratified sediments drape over highs and are dissected by slope canyons and by sediment failures. Failure deposits are widespread on the continental slope and probably consist of rotational slumps and debris-flow deposits. Deeper in the stratigraphy, major sediment drifts are developed.

Piston cores from the continental slope preserve a record proglacial plume sedimentation, including Heinrich layers and distinctive pink layers probably derived from ice exiting Trinity Trough (Fig. 5). This stratigraphy can be correlated into high-resolution seismic reflection profiles (Fig. 6) and used to estimate the recurrence interval of slope failures. Our preliminary work suggests that slope failures are no more frequent on the Orphan Basin margin than elsewhere on the eastern Canadian margin (Piper et al. 2003), with an average recurrence interval of the order of 10 000 years. Much lower recurrence intervals are found for failures on Orphan Knoll (Piper and Toews 2002).

4. GEOHAZARD ASSESSMENT

On the deep basin floor of Orphan Basin, major mass-transport deposits are rare: catastrophically large events have a recurrence interval of the order of 100 000 years. Mass-transport deposits, containing blocks of stiff overconsolidated sediment, may impede drilling operations, particularly jetting. Diapirs indicate that some of the MTD's are unstable. The Western Boundary Undercurrent and the Labrador Current winnow seabed sediments, but concentrations of gravel are unlikely to be so high as to cause an impediment to drilling, except possibly in some MTDs. Lag gravels may occur on channel floors and thick sands may be present on the inner parts of levees. Sediment failures on the continental

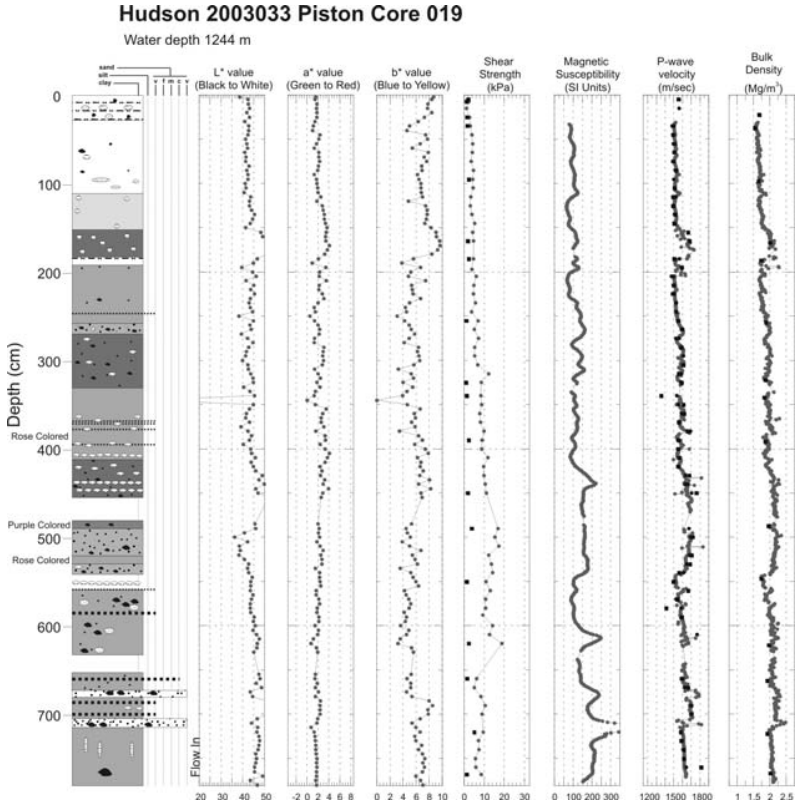

Figure 5- Down-core log of core 19 from the continental slope south of Orphan Basin.

slope are likely earthquake triggered, as elsewhere on the eastern Canadian margin, are infrequent (10 000 year recurrence interval) and probably trigger small debris flows and turbidity currents.

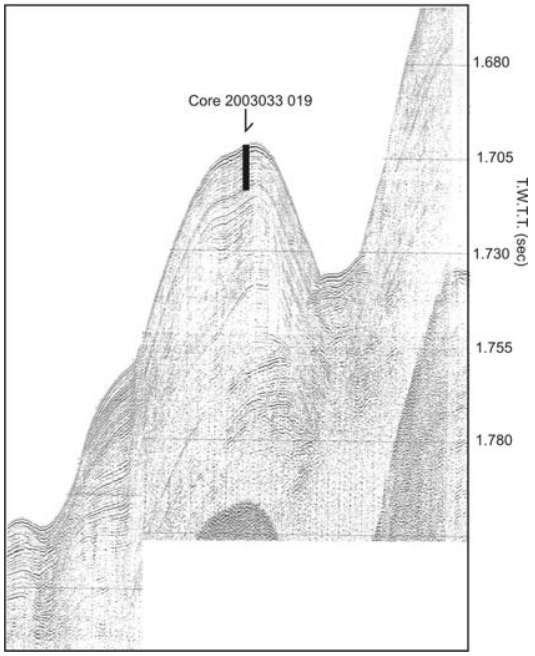

Figure 6- Huntec sparker profile in the vicinity of core 19.

5. ACKNOWLEDGMENTS

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