

Submarine Mass Movements and Their Consequences

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Submarine Mass Movements and Their Consequences

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Dedication

William R. Normark
1943–2008

Bruno Savoye
1959–2008

This book, “Submarine Mass Movements and Their Consequences IV”, is dedicated to the memory of two colleagues whose wide-ranging field studies did so much to advance our understanding of deep-water sedimentation systems: Drs. Bill Normark and Bruno Savoye. I had the good fortune to count them among my closest professional and personal friends. Both were sea-going scientists *par excellence*, both were warm and supportive individuals, who always had time for students, and both were modest about their own accomplishments.

Although many will remember Bill for his work on turbidites and submarine fans, he made important early contributions to our understanding of submarine mass movements. Large slides are a significant component of deep-water terrigenous basins and thus did not escape Bill’s curiosity. In 1968, during his Ph.D. work, he acquired seabed imagery and sub-bottom profiles with the Scripps deep-tow system over Ranger slide off Baja California. His 1974 and 1990 papers on this slide are classic Normark: meticulous use of multiple data sets and a clear mind as to what were the important issues. As Chief Scientist of the GLORIA cruise that mapped the seafloor around the Hawaiian islands, he was the first to appreciate the full extent of the flank-collapse debris avalanches, using the terms “prodigious” and “humongous” in the literature (and “giant” when reined in by editors).

Likewise, Bruno is remembered by many for his work on turbidite systems, but he too worked on submarine slides, particularly earlier in his career. The first paper that he and I worked on together described a slide near the wreck of the *Titanic*, where his colleagues at IFREMER had collected a magnificent survey with the next generation of deep-tow technology, the IFREMER SAR, but just missed the wreck. He is well known for his contributions on the 1979 Nice landslide, which triggered both a tsunami and a turbidity current. Bruno brought his enthusiasm and energy, together with his organisational and analytical skills as an engineer, to the science of turbidites and mass movements. He combined the technological expertise of IFREMER, industry funding and his own instinct of what was necessary to make significant scientific advances at sea.

Mass movements are an important part of the turbidite story. For Bill and Bruno, during much of their careers, mass movements were regarded as the predominant cause of turbidity currents. Both played an important role in challenging that dogma in recent years. Those who study mass movements from the comfort of the seismic work-station or by numerical modelling owe a lot to seagoing scientists like Bruno and Bill who laid the groundwork of where, why and how submarine mass-movements occur in the field.

David J.W. Piper
Halifax, June 2009

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Submarine Mass Movements and Their Consequences

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Introduction

In 1929, an earthquake off the Grand Banks of Newfoundland initiated a submarine mass movement that sheared undersea communication cables and generated a tsunami that resulted in deaths of 27 people along the south coast of Newfoundland. This event initiated the modern realization that the seafloor is a dynamic environment with potential to do harm. More recent catastrophic examples include submarine mass movements off the Nice airport in 1979 that removed part of the runway along with construction equipment and resulted in the loss of several construction workers (Dan et al. 2007; Kopf et al. this volume), and a 1998 event off Papua, New Guinea that caused a tsunami resulting in 2200 deaths (Tappin et al. 2001). On December 26, 2006, a submarine landslide in the Luzon Strait caused failure of undersea cables (Hsu et al. 2009), halting the entire internet network between Taiwan, Hong Kong, and China and affecting communications between Thailand, Malaysia, Vietnam, South Korea and Singapore for 12 h. Given that the combined GDP of Taiwan, Hong Kong and China approximates \$7.56 billion per day, the economic impact of this event was severe. As for the offshore hydrocarbon industry, aside from direct risk to exploration and production platforms, the Society for Underwater Technology estimates that the cost of damage to pipelines caused by submarine mass movements is about \$400 million annually.

As a result of instances like these and the potential economic and societal impact (an estimated 2.75 billion people worldwide live within 60 km of the coast), an interest in understanding the phenomenon of submarine mass movements has led to concerted efforts on behalf of governmental, non-governmental and international agencies to understand this risk to society, e.g. the United States Nuclear Regulatory Commission, the US National Tsunami Hazard Mitigation Program, the European and Canadian Continental Slope Stability (COSTA) Program, the Integrated Ocean Drilling Program and the joint United Nations Educational Scientific and Cultural Organization's (UNESCO) and International Union of Geosciences (IUGS) International Geosciences Program (IGCP) Project 511. The objective of IGCP project 511 is to bring a world-wide perspective to submarine mass movements and their consequences. This objective is realized by assembling

excellent contributions from active researchers, groups and institutions to provide diverse coverage of the many scientific and engineering aspects of this type of marine and coastal geohazard. To this end, this project has hosted four international symposia, the latest of which is represented by this volume. Previous symposia resulted in two books (Lykousis et al. 2007; Locat and Meinert 2003) and a special issue in the Norwegian Journal of Geology (Solheim 2006).

The Fourth International Symposium on Submarine Mass Movements and their Consequences called for manuscript submissions, addressing the broad issues of submarine mass movements, and meeting the objectives of the project to bring together in a common forum experts from all disciplines pertinent to the topic. This volume is the result: a collection of 62 papers spanning subjects broadly organized under topics of: (1) triggers; mechanics and geotechnical properties; (2) case studies and hazard assessment; (3) margin construction and economic significance; and (4) tsunami genesis from submarine mass movements.

Section I: Submarine Mass Movement Triggers, Mechanics and Geotechnical Properties

A fundamental aspect of submarine mass movement research is understanding trigger mechanisms. This research component, however, is not well developed. In this section, authors explore the role of pore pressure and fluid and gas migration in slope instability. As Masson et al. (this volume) indicate, elevated pore pressures are often essential for mass movement initiation, yet understanding how high pore pressures are generated or how fluid migration affects slope stability is limited. Sediments may be pre-conditioned for failure by the processes that originally deposited them, but the processes and parameters that might control this factor are largely unknown. Continental margin development might also result in focussed fluid flow and elevated pore pressures where sedimentation rates are not particularly high, indicating that margin architecture also plays a significant role in overpressure and the most likely place for occurrence of submarine slope failures (Dugan et al. this volume, Urgeles et al. this volume).

In most historic instances, submarine mass movements were triggered by ground accelerations due to earthquakes. Herein lays a paradox; the majority of submarine mass movements and the largest recognized submarine mass movements occur along passive continental margins, where seismicity is not common. It is a rare instance, therefore, that the actual trigger of a submarine mass movement event has been observed and recorded; the first probably being the 1929 Grand Banks event (Heezen et al. 1952 and 1954). Even during events such as earthquakes, ground accelerations may increase horizontal and vertical loads and cause pore pressure responses in specific geologic horizons. Without instrumented in situ monitoring during such events, the actual physical responses of the geologic column to ground accelerations are not known. The paradox above also illustrates that trigger mechanisms need to be properly balanced against preconditioning factors, especially