

Exploring the deep sea and beyond: Contributions to marine geology in honor of William R. Normark (Volume II)

Andrea Fildani¹, David J.W. Piper², and Dave Scholl³

¹The Deep Time Institute, Austin, Texas 78755, USA

²Geological Survey of Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2, Canada

³Emeritus, U.S. Geological Survey

"...fatti non foste a viver come bruti, ma per seguire virtute e canoscenza..."

—Dante Alighieri, *Inferno XXVI*

"Only those who will risk going too far can possibly find out how far one can go."

—T.S. Eliot (1888–1965)

In 2011, we published the first volume dedicated to the scientific achievements of William R. Normark (Fildani et al., 2011). While we were formatting the volume, it became apparent that our colleagues were not done with contributions, as we kept receiving submissions—and for years since. A “spill-over” second volume in honor of Bill became necessary, and the innovative publication style of *Geosphere* was considered well suited to receive the continuous flow of submissions into 2018.

Integration across disciplines, scientific rigor, and masterful synthesis together represent the “core” of Bill’s legacy. This volume includes scientific contributions from recognized experts in different fields from marine geology, sedimentology, tectonics, seafloor geomorphology, and overarching earth sciences. Many times, we have written about how Bill’s comprehensive approach to science and his natural talent for synthesizing large data sets made him the prototype of the modern scientist, but it is with his intuitions and thought experiments that Bill really reached deeply into the earth science community with original insights.

Since Bill’s passing in 2008, there have been advancements in concepts and models that Bill and his closest collaborators helped shape; these recent advancements corroborate some of Bill’s early observations and hypotheses (Fig. 1). For instance, the technological improvements of the automated underwater vehicle (AUV) at the Monterey Bay Aquarium Research Institute (MBARI) have helped illuminate sectors of the seafloor that have been in the “darkness” since humans began speculating about the deepest reaches of the oceans. Because of the new and improved AUVs, marine geologists have been able to map in high resolution the channel to lobe transition zones (CLTZ) on submarine fans, an elusive deep-sea neighborhood that has major implications for applied stratigraphy (e.g., reservoir modeling for giant deep-water fields). Recent images published by Carvajal and colleagues (2017) illuminates the CLTZ where Bill and colleagues first postulated it—the Navy Fan. The newly obtained images would have enthused Bill. CLTZs are fundamental building blocks of deep-sea fans, and two contributions in this volume (Van der Merwe



Figure 1. Bill Normark standing on the forecandle of the R/V Lee, off the Hilina Coast of Kilauea, October 1978. Photo courtesy of Pete Lipman.

et al., 2014 and Pemberton et al., 2016) offer great examples of what we suspect their stratigraphic architectures should look like in outcrop. However, because of the advancements in seafloor mapping we can now improve our predictive models. Enhanced data resolution is having an impact on new conceptual models on how deep-sea channels form and how they transition into the unconfined basin floor. This is a topic Bill helped shape early on with detailed work on Monterey Fan (Monterey East system of Fildani et al., 2006) and the early scoping of the Lucia Chica channel system project (Maier et al., 2013).

On another topic, deep-sea fans—a subject dear to Bill since his early days in marine geology—record new and fascinating insights into important topics such as climate and earth surface processes. Bill’s mentorship led a newer generation of scientists to link deep-water deposits (deep-sea fans) to onshore geology in the early 2000s by quantifying sediment transfer from land to sea and linking the sediment budgets from earth surface processes to the sediment delivered in

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1 figure

CORRESPONDENCE: afild@equinor.com

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the deeper oceans (see Normark and Reid, 2003; Covault et al., 2007; Romans et al., 2009; Covault et al., 2011). These early contributions improved the understanding of the burgeoning field of source to sink (S2S) studies. Bill always thought that deep-water deposits were a reliable tracker of landscape evolution. It is without any doubt that this early 2000s “push” has inspired a series of studies (some published in this volume) that investigate the sedimentary archives of submarine fans with new provenance tools. Recent publications on Bengal Fan (Blum et al., 2018), Mississippi Fan (Fildani et al., 2016), and Indus Fan (Clift et al., 2008) undeniably show the sedimentary records of the largest sediment accumulations on the planet are the “hidden trove” for unraveling the intricacies of tectonics and climates on the continents, as Bill presciently directed. “Old” Deep Sea Drilling Project (DSDP) cores from the Mississippi Fan have been used in the Fildani et al. (2018) contribution in this volume to assess the composition of deep-sea fan lobes. DSDP Leg 96 cruise was the last cruise of the Project, and Bill was one of the principal investigators onboard.

■ VOLUME CONTRIBUTIONS

The history of Bill’s career and the evolution of his scientific methods and interests provide necessary context for the structure of this volume in his honor. The range of papers reflects the broad scope of Bill’s interests and scientific influence.

Bill’s profound appreciation and true love for deep-sea fans inspired many of the contributions, including all the different building blocks of submarine fans, including canyons, fan valleys, channels, and lobes.

McGann (2014), a long-time close collaborator of Bill, presents an approach in which she identifies and interprets the distribution of allochthonous biological sediment constituents in the deposits of the Ascension-Monterey Canyon system, the canyon system feeding the Monterey Fan. The biological constituents have unique environmental signatures that are more precise proxies for source areas than are mineral grains alone. She proposes this approach as a powerful application in the investigation of sediment transport by helping to pick apart staged sediment transport versus full-canyon flushing events.

Mitchell (2014) uses the Monterey Canyon as an example to explore the fundamental processes that are carving submarine canyons. He concludes that sedimentary flows in the canyon produce sufficient basal shear stresses to erode (helped by quarrying and plucking), contrasting his results with denudation processes on the continents above sea level, where continental slopes prograde with time to generate aggrading landscapes.

Adding to the topic of seascape evolution and canyon sculpting, Micallef et al. (2014) present a data set from another submarine canyon system on an active margin, the Cook Strait canyon offshore New Zealand. Their geomorphological analyses highlight the seafloor responses to tectonic activity across the Cook Strait; the canyon’s morphological parameters and response to tectonic activity support a generalized model for canyon geomorphic evolution along active continental margins.

Gamberi et al. (2015) concentrate on the modern canyons carving the slopes off the northern coast of Sicily (Italy). Their detailed seafloor mapping and sequence stratigraphic interpretation confirm that most of the deep-sea fans in the study area received sediment during the current sea-level highstand. These findings consolidate the idea that, particularly along active margins, present-day sediment delivery to the deep sea is relatively common.

Moving down the continental slope profile, Damuth and Olson (2015) concentrate their efforts on the northern Gulf of Mexico Intraslope Basin Province. They present a vast data set that nicely summarizes the Quaternary sedimentary history of this important region of the Gulf of Mexico.

The numerical work of Kostic on net-erosional and net-depositional cyclic steps (Fildani et al., 2006; Kostic and Parker, 2006; Kostic, 2011) is applied to upper flow regime bedforms on levees and continental slopes (Kostic, 2014). Her numerical experiments presented in this volume broaden our understanding of the origin and dynamics of fine-grained upper flow regime bedforms in turbidite systems, specifically on levees.

Channel to lobe transition zones, first introduced by Mutti and Normark (1987), are the main topic of outcropping turbidites in the Magallanes (Pember-ton et al., 2016) and the Karoo (Van der Merwe et al., 2014) basins. These two examples add to the library of outcrops used in applied stratigraphy (reservoir modeling) and offer direct insights into specific deposits on submarine fans. Pyles et al. (2014) interpret channel and lobe elements laterally juxtaposed in a distributive submarine fan system by using the outcrops of the Ross Sandstone of Ireland. The deepest lobes of the Mississippi Fan are the main topic of Fildani et al. (2018) to assess sand deposits and their inferred processes on this sector of the seafloor.

Bill’s interest in tectonically active continental margins is well represented by the book he edited with Homa Lee in which they presciently highlighted the importance of earth sciences to urbanized areas along the continental margins. Their volume, *Earth Science in the Urban Ocean*, collects 20+ years of extensive research on geologic and oceanographic processes in the urban ocean off Southern California (Lee and Normark, 2009).

Many of the manuscripts included in this volume deal with the evolution of continental margins. Walton et al. (2014) offer a great bridge between an actively tectonic margin with a linked deep-sea fan by studying the dynamic response to strike-slip controls on the deposition and evolution of the Baranof Fan, Gulf of Alaska. Their findings suggest that new channel formation, channel beheadings, and southward-migrating channel avulsions have been influenced by regional tectonics, reminiscent of the results presented for the tectonically controlled central California Monterey Fan (Fildani and Normark, 2004).

Sediment delivery into the deeper waters and how the thickness of these sediment accumulations influence earthquakes magnitude along subduction zones are the main topics developed in Scholl et al. (2015). Sediment provenance and controls on slip propagation along the active margin of Japan are tackled by Moore et al. (2015). Active deformation, spatial patterns, and paleoslope estimation from basin-floor mass-transport deposit outcrops in the

Taranaki Basin of New Zealand are reported in Sharman et al. (2015). Langenheim et al. (2013) used new magnetic data to report on an unrecognized regional structure of the Coastal Belt of Northern California.

As is clearly visible in this compilation of contributions, Bill possessed an incredible knack for discoveries, and he influenced many following in his footsteps. The effects of Bill's seminal work will reverberate for years to come.

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