A Conceptual Model of Ice Shelf Sedimentation*

M. W. Mayerle[1] and R. D. Powell[1]

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[1]Department of Geology and Environmental Geosciences, Northern Illinois University, DeKalb, IL, USA (mwmayerle@gmail.com)

Abstract

Modern glacimarine sedimentation can be thought of as a thermal spectrum characterized by two thermal end members: a cold ice (polar) end member typical of higher-latitude margins like Antarctica and Eastern Greenland, and a warm ice (temperate) end member representative of the more mild SE Alaskan and Patagonian systems. Areas with intermediate thermal regimes composed of different ratios of both warm and cold ice (polythermal) like Svalbard fall somewhere in the middle between these two end members. As one gets progressively colder along this spectrum, less meltwater is present in the system as increasingly less ice is below the pressure melting point. The strength of the ice also increases, eventually allowing the formation of a stable floating terminus under certain conditions, called an ice shelf.

Introduction

Sedimentation beneath polar ice shelves at and near grounding-lines is thought to be dominated by debris flows because ice shelves lack a major meltwater component, which results in a considerably more passive deposition relative to more temperate systems. Beneath ice shelves at the grounding-line, sediment accumulates and eventually moves downhill as a glacigenic debris flow creating a series of dipping beds of diamict overlain with horizontal layers of diamict termed a grounding-zone wedge. Passive meltout of debris from the base of the ice shelf occurs for a short distance from the grounding-line contemporaneously, while other minor processes like tidal pumping also act to redistribute fine sediment from the grounding-line.

Previous Work

Sedimentation studies of polar glacimarine systems remain few due to the problem of accessibility below ice shelves. Thus, they remain unobserved aside from an ROV study of Mackay Glacier Tongue (Powell et al., 1996) and conceptual models based on facies, seismic geometries and inferred processes (Powell, 1984; Powell and Alley, 1997; Howat and Domack, 2003). This lack of information is problematic for a geologist who is unfamiliar with the cold ice systems, as applying processes unique to the temperate system to polar systems, results in poor interpretation.

Discussion

This poster focuses on deposition on the cold end of the spectrum beneath a polar ice shelf, introducing both a preliminary conceptual model of ice shelf sedimentation at the continental shelf scale and an update of the most recent depositional model from Howat and Domack (2003). The shelf-scale model is capable of replicating the facies distribution and major landforms found in two Antarctic paleo-ice stream troughs within time constraints dictated by radiometric dating. The shelf-scale model is divided into multiple sections, where each section is divided between meaningful data points in the study area. For example, one section may detail the deposition between two sediment cores, while a different section may cover the deposition of a grounding-zone wedge during a standstill.

The model was digitized and scaled in Adobe Illustrator CS6 with the program's scale function. The model lumps facies into deformation till, glacigenic debris flows (for grounding-zone wedge development), shelfstone mud, and diatomaceous mud. Deformation till mimics Reinardy et al.'s (2011) deforming mosaic model, which agrees with more recent publications and with Powell et al.'s (1996) observation of stiff and soft till occurring syndepositionally, but spatially separated. Shelfstone mud and glacigenic debrites are assigned an average angle of repose for the Antarctic margin, and grow according to a sedimentation rate. Diatomaceous mud sedimentation decreases by half at set distances from the calving line, simulating a logarithmic decay using sedimentation rates measured at the seabed by DeMaster et al. (1998).

Results

This preliminary conceptual model of ice shelf sedimentation functions as an important stepping-stone for future research, as no model at this scale exists in the literature. We hope that the ideas and processes used in this simple conceptual model will be expanded on by future researchers in a more rigorous computational model. A small portion of the shelf-scale model showing a section from the JOIDES Basin is shown in Figure 1. An update to figure 3 of Howat and Domack's (2003) depositional model of ice shelf sedimentation is also presented. This update adds scale, a third dimension, a decade of research on new geologic/glaciological processes, depositional bias', and greater specificity to the model. Howat and Domack's (2003) model is split into two areas and includes a corresponding idealized retreat core. One area focuses on the calving line and the other on the grounding-zone area. The grounding-zone section of the model update is shown in Figure 2.

The corresponding hypothetical idealized sediment core shows all expected facies deposited by an ice shelf starting subglacially and ending in the open ocean environment past the calving line. Important subdivisions of facies, geophysical data, diatom data, and more depositional environments have been added to the core.

Conclusions

As petroleum exploration continues and expands at high latitudes, it is becoming increasingly necessary to address the lack of data associated with the cold end of the thermal spectrum, especially beneath ice shelves. Increased understanding of the cold end of the spectrum will aid in the overall understanding of glacimarine sedimentation. Many locations have fluctuated between a warmer and a cooler glacimarine system over time, resulting in areas with both temperate, polythermal, and polar deposits stacked above each other. The ability to distinguish between these is extremely important for proper interpretations. Additionally, new intermediate forms between grounding-line fans and grounding-zone

wedges such as the landforms observed by Bjarnadóttir et al. (2012) in the western Barents Sea would be easier to place and interpret if the polar end member was more clearly defined.

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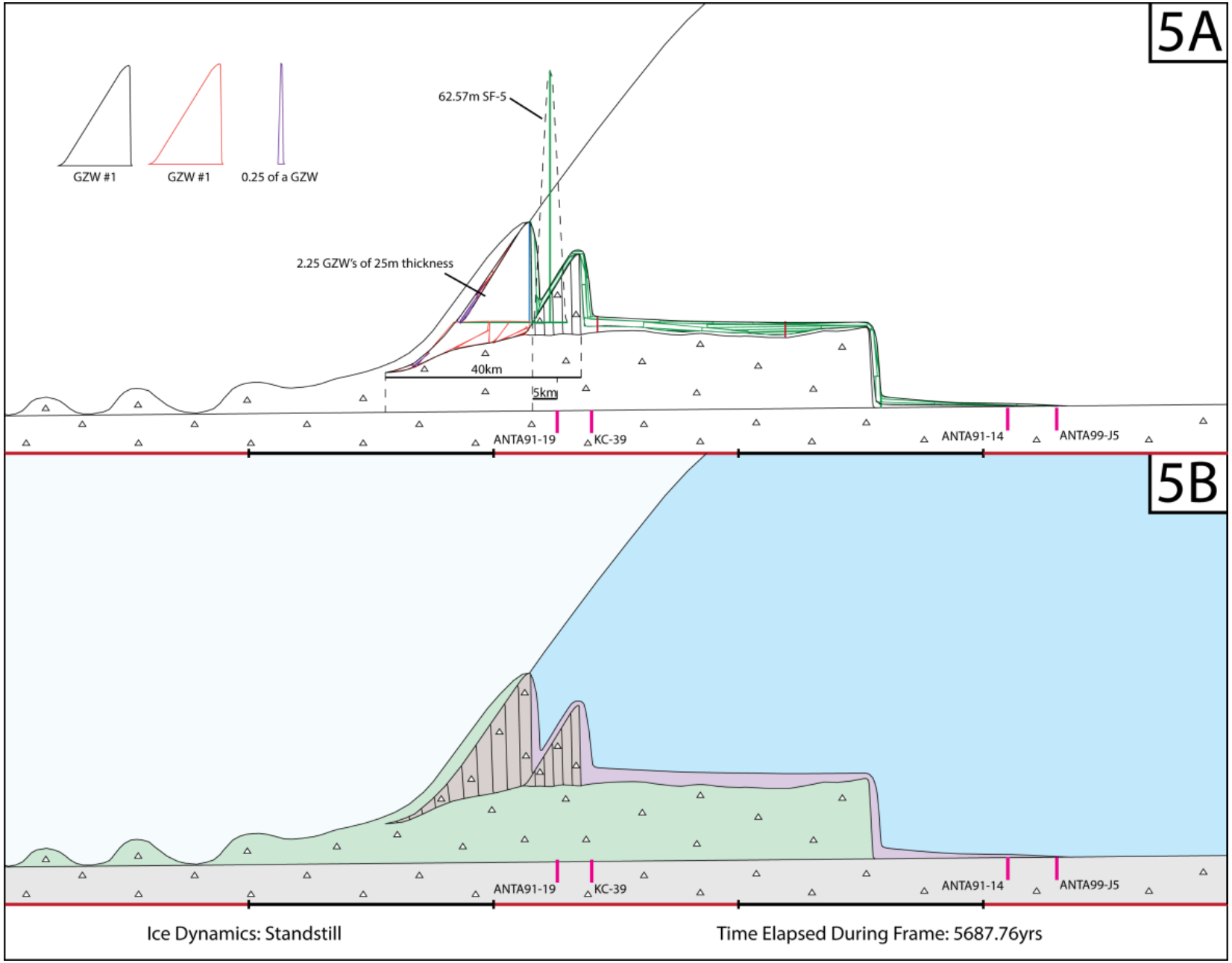

Figure 1. A small portion of the continental shelf scale model of the JOIDES Basin test.

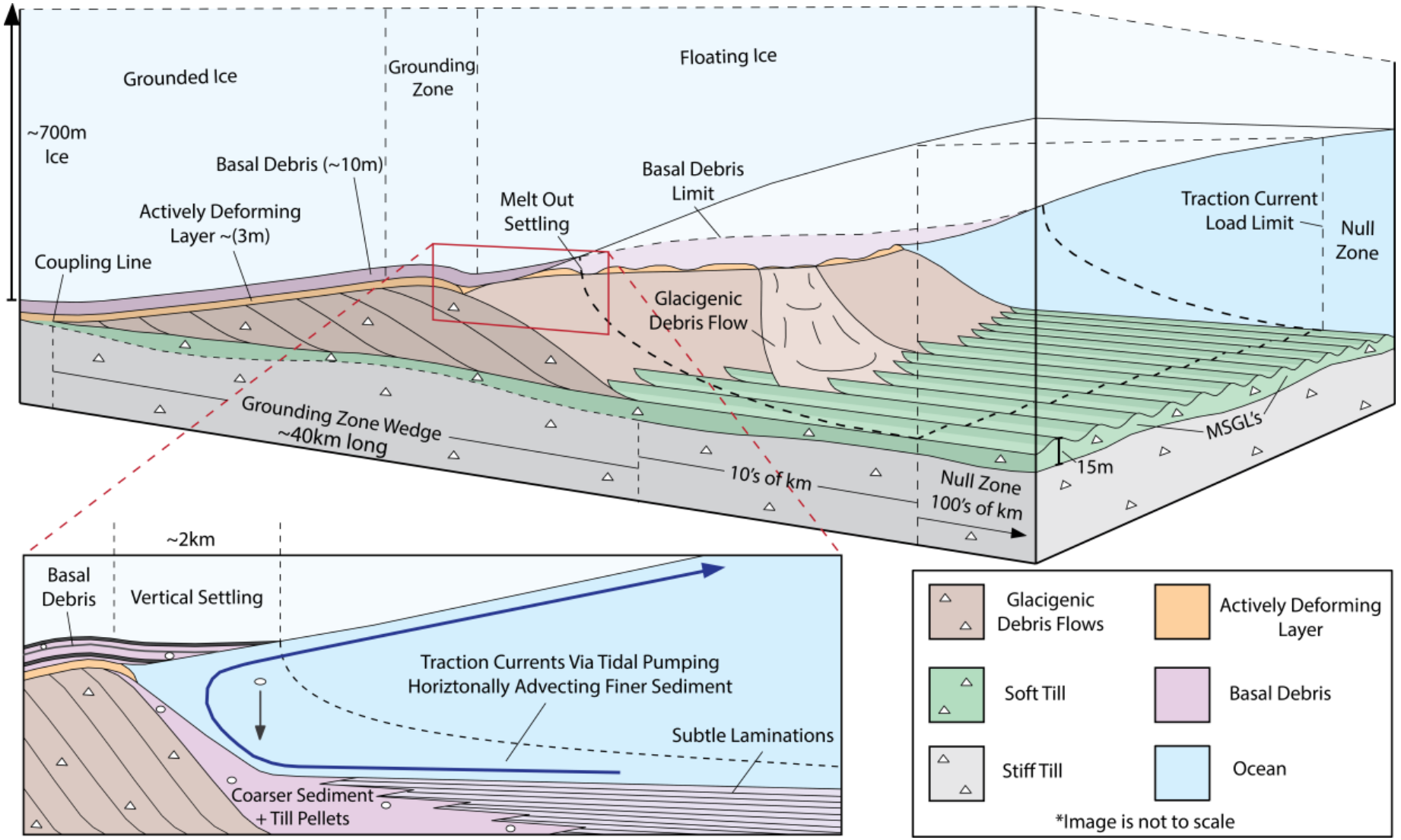

Figure 2. Sedimentation at the grounding-zone of a polar ice stream with a floating terminus. Image is scaled similarly to the modern Ross Ice.