Abstract

Building High-Latitude Sequence Stratigraphic Models, with Examples from Eocene Through Miocene Successions on the Antarctic Continental Margin

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Here we summarize sedimentary facies, laser particle size, and bulk geochemical data acquired on drillholes on the Antarctic continental margin to build high-latitude sequence stratigraphic models. Several overlapping drillholes within three drainage basins span the Eocene to Miocene, an interval of major ice growth in Antarctica. Studying transects of cores across major ice growth events provides important insight into the stratigraphic signature of ice growth and retreat. In Antarctica, because of the presence of the ice cover, the shelf successions are key to interpretations of the characteristics of the terrestrial sediment routing system and inform interpretations of sediment provenance and dispersal to the Southern Ocean. The effects of ice growth and retreat on deep-water processes and phytoplankton systems are visible in drillholes from the continental rise.

Based on sequence stratigraphic models derived from low-latitude continental margins or small ice sheets, fining upward glacigenic successions are interpreted either as evidence of glacial retreat or an increase in paleo water depth. Two approaches exist: one model identifies periodicities in the stratigraphic record that can be tied to glacial variations. However, the model is not intended to identify the magnitude of shifts in the grounding line of the ice sheets or glaciers as it does not consider the variable ice-proximal and ice-distal depositional environments for diamictites. On the other hand, the second model explains the occurrence of glacial advance and retreat of tidewater glaciers, but not for ice sheets with glacial maxima beyond the present interglacial stage. Clearly, the sequence stratigraphic models could benefit from studies of lateral transects tied together with analytical data to enhance the sedimentological interpretations.

One important factor often ignored in the interpretation of high-latitude icehouse successions is the considerable influence of geodynamic processes near large continental ice sheets and their effects on relative sea level. Recent advances in geodynamic modeling have brought these effects to the forefront of the discussion. Contrary to the current sequence stratigraphic models applied to Antarctic continental shelf successions, geodynamic models predict a relative sea level (RSL) rise upon ice sheet expansion over a wide area of the continental shelf due to the cumulative effects of glacio-isostasy and self-gravitation (the gravitational pull of the ice-sheet's mass). The RSL changes, therefore, are strongly time-transgressive leading to distinct differences in RSL between time-equivalent ice-proximal and ice-distal sedimentary successions. Geodynamic processes associated with ice dynamics generate the most rapid paleobathymetric responses of glacially influenced continental shelves and may result in local sea level variations opposite to the eustatic trend. These processes also alter the relationship between eustasy and active submarine fan phases on a high latitude continental rise.

We investigate in detail the relationship between ice growth, geodynamic effects, and sedimentation through studies of drillholes within a framework of seismic interpretations. The Eocene to Miocene interval on the Antarctic continental margin is particularly suitable to study this relationship, because of large increases in ice volume. Reconstructing continental-scale ice sheet inception from lithofacies analysis alone, however, has led to controversy in interpretations of diamictite-dominated continental shelf successions. Here, geochemical methods can provide critical supporting evidence for interpretations based on lithostratigraphic considerations. Due to poor preservation of carbonate, our approach is based on bulk sediment ICP-AES data and builds on emerging evidence that the chemical depletion of alkali and alkaline Earth elements in soils is primarily coupled to the prevailing climate. Because alkaline elements are strongly partitioned in the detrital fraction of marine sediments, we can evaluate the bulk major element geochemistry of continental margin sediments through the use of soil climofunctions, an approach similar to the application of clay mineralogy to marine sediments. An integrated stratigraphy with geochemical parameters provides a unique opportunity to reconstruct ice advance and retreat on the Antarctic continental margin for the Eocene to Miocene.

We define the onset of continental scale ice growth in our records where the shift occurs from chemically to physically weathered sediment as expressed in the CIA (or CIA-K) calculated from the bulk major element geochemistry. Bulk ICP-AES data is relatively easy to collect and chemostratigraphic correlation of drillholes using CIA-K allows us to significantly enhance the lithofacies interpretaions that are currently applied to the margin based on single drillholes. Using an integrated approach we refine glacial sequence stratigraphic models for deposition near large ice centers. Our results help to understand the lateral correlations between outcrops and drillholes and benefit the understanding of glaciogenic successions in other parts of the rock record, such as the Proterozoic and Paleozoic icehouse stratigraphy.