Sequence stratigraphy and facies analysis of the Friis Hills Drilling Project drillcore: Towards a reconstruction of Early to Mid-Miocene East Antarctic Ice Sheet variability

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Abstract

Understanding the response of the Antarctic ice sheet to past climatic variability provides important context for understanding how the ice sheet will respond to future climate change under high CO_2 scenarios. Future projections show atmospheric CO_2 concentrations could reach 600 ppm well before the end of the century (IPCC, 2013) with associated global temperatures 4-5°C warmer – a climate not seen since the middle Miocene (17-15 Ma; e.g. Gasson *et al*. 2016). This time period is becoming increasingly important as a future analogue because atmospheric CO_2 has already reached Pliocene levels. Moreover, the paleogeography, and therefore, atmospheric and oceanic circulation during this time were relatively similar to present day configuration providing a representative "test-bed" for understanding future Antarctic Ice Sheet (AIS) change.

Previous studies have suggested that the AIS was highly sensitive to small changes in atmospheric CO_2 during this time period, resulting in a dynamic ice sheet with major cycles of expansion and contraction (Levy *et al.* 2016). Antarctic Miocene glacial history relies heavily on proximal marine sedimentary records such as Cape Roberts (2 and 3) and ANDRILL-2A to reconstruct environmental conditions. However, these cores do not record terrestrial environments, but can be correlated with other terrestrial deposits from the Olympus and Asgard Ranges, in the Transantarctic Mountains, which record changes in both glacial dynamics and vegetation (Marchant *et al.* 1993; Lewis *et al.* 2007). They describe a shift from temperate climate wet-based glaciation to a polar dry glacial style at the time of the mid-Miocene climate transition ~13.9 Ma (Stroeven and Kleman 1999; Lewis *et al.* 2007, 2008).

We present the initial findings from a series of permafrost drill cores recovered from Early to Middle Miocene (~19-15 Ma) fossiliferous glacifluvial/lacustrine deposits in Friis Hills, Transantarctic Mountains (TAM), previously described from surface pits and sporadic outcrops (Lewis and Ashworth 2016). During the austral summer season of 2016/17, three sites were drilled up to a depth of 50.48m into a locally-preserved basin, whose stratigraphic geometry had previously been defined by an active source seismic survey in November 2014. Lithostratigraphic descriptions and a preliminary facies analysis supported by physical property measurements (magnetic susceptibility, velocity and density) of the cores identify 9 episodes of glacial advance and retreat of a relatively local alpine glacial system connected to the East Antarctic Ice Sheet. The stratigraphic architecture of sedimentary cycles in the cores is defined by a characteristic vertical stacking pattern of repetitive facies successions bounded by glacial surfaces of erosion. Ten sedimentary facies have been identified representing regular oscillations in a depositional setting along a continuum from subglacial to ice distal lacustrine environments.

These geological records offer direct evidence of East Antarctic Ice Sheet variability in the TAM during the warmer-than-present Miocene. The range of facies in the cores and the associated biota described by Lewis and Ashworth (2016) indicate a considerably warmer and wetter climate, characteristic of temperate alpine glacial environments found at treeline in present-day Patagonia. Uncertainty over uplift rates in the TAM since the Miocene complicates paleoclimatic interpretation. Inferred rates of up to 100 m my^{-1} (Fitzgerald 1992) place the Friis Hills, with an average modern day elevation of 1325m, considerably closer to sea level during the time of deposition. These constraints on terrestrial climate and glacial conditions will then be compared with equivalent age marine sediments in ANDRILL-2A and used as boundary parameters for future ice sheet model simulations.

Keywords: Miocene, Friis Hills, sequence stratigraphy, ice sheet

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