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Sea ice extent and seasonality for the Early Pliocene northern Weddell Sea

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ABSTRACT

Growth increment analysis coupled with stable isotopic data ($\delta^{18}O/\delta^{13}C$) from Early Pliocene (ca 4.7 Ma) *Austrochlamys anderssoni* from shallow marine sediments of the Cockburn Island Formation, northern Antarctic Peninsula, suggest these bivalves grew through much of the year, even during the coldest parts of winter recorded in the shells. The high frequency fluctuation in growth increment width of *A. anderssoni* appears to reflect periodic, but year-round, agitation of the water column enhancing benthic food supply from organic detritus. This suggests that *Austrochlamys* favoured waters that were largely sea ice free. Our data support interpretation of the Cockburn Island Formation as an interglacial marine deposit and the previous hypothesis that *Austrochlamys* retreated from the Antarctic as sea ice extent expanded, this transition occurring during climate cooling in the Late Pliocene.

1. Introduction

The Pliocene Epoch (5.3 to 2.6 Ma) spans a time when the Earth experienced a transition from relatively warm conditions to a cooling climate that heralded the high magnitude glacial–interglacial oscillations of the Pleistocene Epoch (Haywood et al., 2009). The warm interglacial climates of the Pliocene may be plausible comparative scenarios for interpreting the path of future climate warming during the 21st century (Jansen et al., 2007; Haywood et al., 2009). Whilst overall global climate may have been 2–3 °C warmer during the 'mid Piacenzian warm interval' (= 'mid Pliocene warm period' of earlier papers), climate at high latitudes is modelled to have been much warmer than today (Haywood et al., 2007a,b and references therein). Given the significance of a warming 21st century global climate and its influence on high latitude sea surface temperatures and sea ice extent, it is important to develop proxies that can ground-truth models of high latitude regions during the Pliocene (e.g. Dowsett, 2007, Fig. 6).

Bivalves preserve a signal of marine seasonality (e.g. water temperature, upwelling, food supply) in their carbonate geochemistry and skeletal morphology (e.g. Jones and Quitmyer, 1996; A. Johnson et al., 2000, 2009; Schöne et al., 2003, 2005). These signals have been used to provide climate information across a range of palaeolatitudes (e.g. Williams et al., 2009). Antarctic Peninsula Neogene fossil bivalves have received detailed taxonomic and environmental appraisal (e.g. Jonkers et al., 2002; Jonkers, 2003) but they have not been used to assemble a record of seasonality. Nevertheless, Berkman et al. (2004) have presented a cogent argument, based on morphological and sedimentological analyses, which suggests that the retreat of *Chlamys*-like bivalves from the Antarctic resulted from increasing sea ice cover during the climate cooling of the Late Pliocene.

The pectinid bivalve *Austrochlamys anderssoni* occurs commonly in rocks of Late Miocene through Pliocene age on the northern Antarctic Peninsula. *Austrochlamys anderssoni* is ideal for investigation of palaeoseasonality as specimens are large, often reaching greater than 10 cm from umbo to margin in adults, and record a number of seasons of growth. In addition, the width of individual growth increments in *A. anderssoni* is easy to measure (mm-scale), and they are correspondingly easy to sample for geochemical analysis. Here we analyze ontogenetic patterns in *A. anderssoni* to test for the extent of sea ice in the northern Weddell Sea during a warm interval of the Early Pliocene. We test two possible marine scenarios: 1), that there was extensive winter sea ice with no planktonic food-supply, no re-suspension of detrital food and therefore limited or no bivalve growth, an environment suggested by some climate models (see Figs. 1 and 2),

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