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Spread of Ice Sheet during Late Eocene Event Before Major Ice Growth at the Eocene-Oligocene Transition

KEEHWAN LEE[1], LUCIEN NANA YOBO[1], MICHAEL BIZIMIS[2], HOWARD SCHER[2] AND FRANCO MARCANTONIO[1]

[1]Texas A&M University
[2]University of South Carolina
Presenting Author: khlee1009@tamu.edu

The Eocene-Oligocene Transition (EOT; ~34 Ma) represents one of the most notable global climate change events in the Cenozoic, because it marks the onset of Antarctic ice sheet development. During ice sheet development, there is increased mechanical weathering due to friction of the ice as it proceeds toward the coastline. This physical process can be used as a proxy for ice sheet growth and, we hypothesize, can be tracked with radiogenic hafnium isotope ratios ($^{176}Hf/^{177}Hf$) to reveal the timing and location of ice sheet advances. Here, we measure $^{176}Hf/^{177}Hf$ of the sortable-silt-sized fraction (SS; 10-63 μm) of bulk sediments from ODP Site 689D (Maud Rise) to constrain the relative timing of the onset of ice sheet development. Results show no discernible pattern in the $^{176}Hf/^{177}Hf$ of the fine (<10 μm) and coarse (>63 μm) fractions. The $^{176}Hf/^{177}Hf$ of bulk sediment samples, however, decrease during the 'Late Eocene Event' event at 34.15 Ma (LEE; 34.15 to 34.44 Ma, known as failed glaciation event; Hutchinson et al., 2020). Interestingly, the $^{176}Hf/^{177}Hf$ in the SS fraction show two episodes of decreasing values, during a 'Late Eocene Event' at 34.18 Ma and 34.41 Ma. These drops in $^{176}Hf/^{177}Hf$ of the SS fraction coincide with maxima in oxygen isotope ratios, which are widely interpreted as evidence for cooling events. We suggest that the $^{176}Hf/^{177}Hf$ of the fine and coarse fractions, and the bulk sediment itself (which is comprised of all fractions), are not good indicators for tracking growth of the ice. The $^{176}Hf/^{177}Hf$ of the SS fraction, on the other hand, more accurately reflect the growth of the ice sheet. Our data supports the idea, therefore, that the first expansion of the Antarctic Ice Sheet occurred during what once previously believed to be a failed glacial event, i.e., LEE, at 34.15 Ma and 34.41 Ma, 150 and 410 thousand of years earlier than what others have predicted to be the initiation of Antarctic ice growth (34.0 Ma; Howie Scher et al., 2011).

[1] Goldschmidt, Hutchinson et al., (2020), *Climate of the Past Discussions 2020*, 1-71

[2] Goldschmidt, Howie et al., (2011), *Geology* 39 (4), 383-386