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The Big Freeze: Diatoms record Arctic sea ice at 47 Ma

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Early middle Eocene (50-45 Ma) oceanic sediments drilled by Integrated Ocean Drilling Program (IODP) Expedition 302, "The Arctic Coring Expedition" (ACEX) contain abundant marine and freshwater siliceous microfossils. Diatoms are the most diverse group and comprise, on the whole, endemic and typically heavily silicified Paleogene assemblages characterised by *Hemiaulus* spp. Surprisingly, species of the finely silicified diatom *Synedropsis* are also preserved from 47 Ma, contributing up to 60% of the assemblages and with colony integrity commonly still intact. We show from multiple lines of evidence that, as for extant species of this genus, *Synedropsis* spp. were dwelling in sea ice rather than components of the sea ice-associated plankton. This discovery is unusual since sea ice dwelling diatoms are generally too delicate to be preserved in the fossil record. Their presence in the ACEX sediments predates existing sea ice-related diatom records by 16 Myr in Antarctica and by 37 Myr in the (sub)Arctic. The ACEX *Synedropsis* spp. therefore represent the earliest known fossil record of sea ice diatoms.

One of the earlier key results of ACEX had been the unexpected discovery of ice rafted debris (IRD) in long core sediments dating back to the middle Eocene (46 Ma) (Moran et al., 2006, Nature, 441; St. John, 2008, Paleoceanography, 23). Although IRD transportation by both icebergs (glacial) and sea ice was acknowledged in these earlier works no further attempt was made to define which type of ice was dominant or the temporal significance of either. *Synedropsis* spp. not only prove that sea ice was present in the middle Eocene Arctic since 47 Ma, but that it was stable enough to have supported a significant biomass at this time. Our data record the critical transition from an ice-free to a sea ice-dominated environment at the very start of the long term Cenozoic climatic cooling trend. Importantly, *Synedropsis* spp. may be a means by which to determine the extent of middle Eocene sea ice in the central Arctic and its temporal fluctuations during this critical phase. Since very little is still known about the early sea ice history of the region, this makes an important contribution towards understanding the past cryospheric patterns of the region, and will be invaluable for planning future drilling projects to the area.