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Radiocarbon dating of sediments using ramped pyrolysis and its application to the event stratigraphy in the Arctic Ocean

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学位論文の要約

The glacial period is characterized by millennial-scale abrupt climate variability. Changes in the Atlantic meridional overturning circulation (AMOC) are considered as one of the causes of this millennium-scale climate change. The salinity of the surface water of the North Atlantic is a key of the regulation of the AMOC (Broecker et al., 1989). The meltwater inflow from the Laurentide ice sheet is a most likely trigger to change the AMOC during the last glacial and deglacial periods (Manabe and Stouffer, 1995; Rahmstorf, 2002, 2003; Böhm et al., 2015). However, the timing and route of meltwater from the Laurentide ice sheet during the last deglaciation and those effect to the millennial-scale climate changes are under discussion (Broecker et al., 1989; Condron and Winsor, 2012; Carlson et al., 2007; Murton et al., 2010; Tarasov and Peltier, 2005). the salinity drop in the western Arctic at the offshore of the Mackenzie delta at the onset of the Younger Dryas (YD) period was indicated by the negative $\delta^{18}O$ excursion of planktic foraminifera in sediment cores from the Makenzie delta area (Keigwin et al., 2018). The data of Keigwin et al. (2018) indicated that freshwater discharge continued during the Bølling-Allerød (BA) period (14.5-12.9 ka) before the YD period, though the degree of negative excursion of $\delta^{18}O$ was smaller than that at the onset of the YD period. However, the AMOC did not weaken during the BA period (Ritz et al., 2013). This disagreement suggests that the response of the AMOC to freshwater input was not simple. The identification of route of freshwater discharge from the Laurentide Ice Sheet to the Arctic Ocean during the BA period is important to understand the relationship between freshwater discharge and the AMOC. In this study, I refined the stratigraphy of western Arctic Ocean sediments and discussed the sediment provenances and sedimentation processes of event layers during the last glacial period. A new empirical calibration method was developed to more accurately determine the sediment age of the carbonate-lean sediments in the western Arctic Ocean. Based on the established stratigraphy with age controls, I calculated the amount of meltwater which flowed from the Laurentide ice sheet into the Arctic Ocean during the BA period and discussed the relationship between the AMOC and the freshwater inflow to the Arctic Ocean during the BA period.

Radiocarbon (^{14}C) dating of biogenic carbonates is commonly used for marine sediments up to 50 ka old. However, carbonate-poor environments, typical for polar seas, limit the possibilities for ^{14}C dating, while its application to bulk organic matter (OM) is typically biased by the old carbon. A recently developed method of ramped pyrolysis (RP) ^{14}C dating of bulk OM was successfully applied to carbonate-poor Holocene sediments from the Antarctic margin (Rosenheim et al., 2008, 2013; Subt et al., 2016, 2017). We capitalize on the independent age constraints for the analyzed sediments developed in prior studies on the same or correlative cores (Darby et al., 2009a; Lisé -Pronovost et al., 2009; Keigwin et al., 2018). Two piston sediment cores, HLY0501-JPC5 and -JPC6 were collected from the NW Alaskan margin in the western Arctic Ocean during the 2005 Healy-Oden Trans Arctic Expedition (HOTRAX'05; Darby et al., 2009a). A comparison of these ages with the RP 14C data enabled us to develop a new, empirical method of determining the actual age of sediment from the pyrolyzed organic components. Application of RP to these sediment samples yielded a series of volatile carbon of progressively older ages with increasing pyrolysis temperatures and with sediment depth. The difference between the independently constrained initial and the RP-derived ages was proportional to the gradient of ^{14}C ages of the released carbon vs. the pyrolysis temperature. Using this empirical relationship, we propose a new method to estimate sediment age based on RP 14C data. Ages derived by this method in our data set show offsets from the initial ages mostly within ~700 and 1,700 years for the conventional and calibrated ages, respectively. If verified in other data sets, this simple method may have a broad application to sediments with biogenic carbonate deficiency, whereby dating is reliant on bulk OM.

Paleoceanographic research in the Arctic Ocean began by Russian scientists using ice island stations in the 1950s (Belov and Lapina, 1961). The Mn-rich brown layer and the Mn-poor gray layer correspond to the warm interglacial/interstadial and cold glacial/stadial periods, respectively (Jakobsson et al., 2000; Backman et al., 2009; Polyak et al., 2004, 2007). Detrital dolomite-rich layers exist in Arctic Ocean sediments and are useful for stratigraphic correlation (Darby et al., 1997; Bischof et al., 1996). Moreover, the provenance of the sediment in the Arctic Ocean was discussed based on terrestrial-origin OM composition (Yamamoto et al., 2008; Yamamoto and Polyak, 2009), the composition of oxide minerals (Darby et al., 2002) and mineral composition (e.g., Krylov et al., 2008; Kobayashi et al., 2016; Yamamoto et al., 2017). In this study, we analyzed the ice rafted debris (IRD) abundance, grain size distribution, mineral composition, total organic carbon (TOC), total sulfur (TS), total nitrogen (TN) and glycerol dialkyl glycerol tetraethers (GDGTs) to establish the stratigraphy of western Arctic Ocean sediment. In this study, seven sediment cores were analyzed. The stratigraphy of western Arctic Ocean sediments was established based on lithological and geochemical properties. Dolomite-rich layers are useful for high resolution correlation of western Arctic Ocean sediments. A unique kaolinite-rich layer (K layer) was recognized from the 13.2-14.5 ka intervals (BA period) in the western Arctic Ocean sediment sequence. The sediments of the K layer most likely originated from inland Canada through the proto-Mackenzie River. The sediment property suggests that the sediments were transported by strong water stream rather than sea ice/iceberg drifting.

Global sea level rose by 25m during the BA period (Yokoyama et al., 2018). The freshwater inflow into the ocean during this period, however, did not affect the AMOC (Ritz et al., 2013). In this study, we estimated the amount of meltwater which flowed from the Laurentide ice sheet to the Arctic Ocean during the BA period. From the deposition area and thickness of the K layer found in this study, the volume of sediment transported by meltwater during the BA period was estimated. Assuming the density of turbid water which carried the sediments, I obtained the amount of freshwater. The minimum deposition area and thickness of the K layer deposited on the BA period, which was clarified in this study, enables us to estimate the amount of freshwater required to transport this sediment. the total volume of the K layer is estimated to be 917.5 km^3. This indicates 9.4 times higher sediment discharge than that of the present Mackenzie River.

Rough-estimation indicates the freshwater discharge rate was 2 ~ 4 times higher than that of today. The total discharged water amount corresponds to a model estimate of the increased amount of sea water during the BA period. This water discharge did not seem to affect the AMOC.