doi:10.3724/SP.J.1085.2011.00205 December 2011 Vol.22 No.4 205–214

Stable oxygen and carbon isotopes from the planktonic foraminifera *Neogloboquadrina pachyderma* in the Western Arctic surface sediments: Implications for water mass distribution

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Received August 1, 2011; accepted October 10, 2011

Abstract *Neogloboquadrina pachyderma* is the most abundant planktonic foraminifera species found in the modern polar oceans. The δ^{18}O and δ^{13}C of *N. pachyderma* from the Western Arctic Ocean sediments were analyzed to reveal the implications of the proxies to environmental changes. The δ^{18}O from *N. pachyderma* in the Chukchi Sea reflect the water mass distribution in this area. Heavier δ^{18}O values were found along the Anadyr Current (AC) and lighter values in the central and eastern Chukchi Sea. These may reflect the freshwater signal from the Alaska Coastal Current (ACC) and Bering Sea Shelf Water (BSSW). The light δ^{18}O signature in the high Arctic basin comes from the freshwater stored in the Arctic surface layer. The δ^{13}C distribution pattern in the Chukchi Sea is also influenced by the current system. High primary productivity along the AC results in heavy δ^{13}C. The relatively low primary productivity and the freshwater component from the BSSW and ACC may be the reason for this light δ^{13}C signal in the central and eastern Chukchi Sea. Our data reveal the importance of well ventilated Pacific Water through the Chukchi Sea into the Arctic Ocean.

Keywords δ^{18}**O**, δ^{13}**C**, ***Neogloboquadrina pachyderma***, **Western Arctic Ocean**

Citation: Xiao W S, Wang R J, Cheng X R. Stable oxygen and carbon isotopes from the planktonic foraminifera *Neogloboquadrina pachyderma* in the Western Arctic surface sediments: Implications for water mass distribution. Adv Polar Sci, 2011, 22: 205–214, doi: 10.3724/SP.J.1085.2011.00205

0 Introduction

The Arctic Ocean is surrounded by continents and the largest shelf areas on earth. It is connected to the Atlantic and Pacific Oceans via narrow Fram Strait and the shallow Bering Strait, respectively. The Arctic Ocean is strongly influenced by riverine input, which is responsible for ∼10% of total global river runoff[1–2]. Seasonal sea ice variation modulates the heat balance of the Arctic Ocean through the sea-ice albedo effect[3]. Along with global warming, the fast melting of sea ice amplifies the change in global climate[4]. The wider open water territory could be an important area as a future global carbon sink[5], although some recent studies suggest less amount of CO_2 drawdown in the Arctic Ocean than expected[6]. It is closely related to biological productivity, water properties and structure (e. g., freshwater input, ventilation, stratification) in the Arctic Ocean.

Neogloboquadrina pachyderma(formerly known as *N. pachyderma* sinistral form[7]) is the dominant plantonic foraminifera species in the high latitude oceans. The stable oxygen and carbon isotopes (δ^{18}O and δ^{13}C) of this species have become important tools for reconstructing Arctic surface water properties[8]. They have previously been used as proxies for surface water properties/ocean

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circulation[9–13], sea ice formation[14] and melt water events[15–16]. However, those studies are mainly focused on the Eastern Arctic Ocean[9] and data is still very limited from the western side of the Arctic Ocean.

In this study, we analyzed the δ^{18}O and δ^{13}C of *N. pachyderma* from the surface sediments of the Western Arctic Ocean recovered during the first and second Chinese National Arctic Research Expeditions. The sediments are from the Chukchi Sea, the Beaufort Sea and the Canadian Basin, covering a wide area of the Western Arctic Ocean. Because *N. pachyderma* are likely to calcify their tests during the summer months[17], we discuss the relationship between the δ^{18}O and δ^{13}C of *N. pachyderma* with summer water properties. We then use these relationships to examine any implications from this proxy for paleoceanographic reconstructions in the Western Arctic Ocean.

1 Oceanographic settings

1.1 Ocean currents

The Chukchi Sea is a marginal sea in the Western Arctic Ocean, with an average water depth of ~50 m. It connects the Pacific Ocean via the Bering Strait, and is strongly influenced by the Pacific Ocean[18]. Three water masses flow through the Bering Strait from the Pacific Ocean. From west to east they are the nutrient rich Anadyr Current (AC), characterized by relatively high salinity and low temperature, the Bering Sea Shelf Water (BSSW) and the warm and fresh Alaska Coastal Current (ACC) (Figure 1). From the northwest, the Siberian Coastal Current (SCC) flows into the Chukchi Sea via the Long Strait[19–21]. The Canadian Basin is dominated by the clockwise circulating Beaufort Gyre. The Atlantic water enters the Arctic through Fram Strait and the Barents Sea and sinks to about 200 m, becoming Arctic Intermediate Water that circulates anti-clockwise[22–23]. The Arctic Ocean also receives large amount of fresh water from the rivers in the surrounding continents. For example, approximately 307 km^3·a^{-1} of freshwater and 10^6 t·a^{-1} of sediment from the Mackenzie River are transported to the Beaufort Sea[1–2].

1.2 Temperature and salinity distribution in the Western Arctic Ocean

According to the hydrological survey during the second Chinese National Arctic Research Expedition in 2003

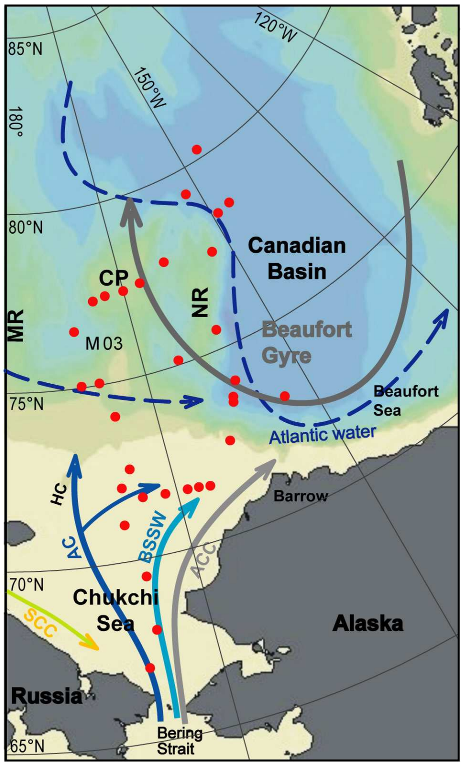

Figure 1 Site map and oceanographic setting[18–23] of the Western Arctic Ocean (see also Table 1). AC: Anadyr Current, BSSW: Bering Sea Shelf Water, ACC: Alaska Coastal Current, SCC: Siberian Coastal Current, CP: Chukchi Plateau, NR: Northwind Ridge, MR: Mendeleev Ridge, HC: Herald Canyon. The dashed line denotes the subsurface Atlantic water.

(Figure 2), the surface water (i.e., 0 m) in the east Chukchi Sea along the Alaska coast is 2℃–3℃ higher than the west side, north of 71°N. Additionally the water temperature gradually becomes uniform at high latitudes decreasing from 0℃ to~–1.5℃ towards north, as a transitional area from the open water to the sea ice covered water. At 50 m depth, the difference in water temperature between east and west Chuckchi Sea reduces, still showing a cooling trend northward. North of 71°N the water temperature is around –1℃—–1.5℃ whereas in the Beaufort Sea it is 0.5℃ to 1℃ higher than the Chukchi Plateau and Northwind Ridge area. Due to the shallow Chukchi Sea shelf area, the hydrological sites for water deeper than 100 m are north of the Chukchi Slope. At 100 m, the Chukchi Plateau, Northwind Ridge area and the Canadian Basin are uniform in water temperature (–1℃—–1.5℃). However, the Beaufort Sea is still warmer than the other regions. At 150 m, the area of 74°N to 75°N, 170°W is –0.5℃—–1℃, warmer than the surrounding area by ~0.5℃. From the Canadian Basin towards the Beaufort Sea, the temperature increases from –1.5℃ to~–1℃ in the coastal area. Compared to 150 m, at 200 m depth the water temperature at the continental slope area is 0.5℃ to 1℃ colder, but in the central basin area it is warmer by about 0.5℃. These features indicate the influence of the intrusion of warm Atlantic water at subsurface depth.

The salinity of the Western Arctic show that the surface water salinity in the Chukchi Sea is low in the east and high in the west (Figure 2). It manifests the properties of the ACC and the AC and the high latitude Arctic basin is characterized by lower salinities due to high sea ice cover. The lowest salinity (~28‰) occurs in the central Canadian Basin. At 50 m, the salinity in the Canadian Basin (~31.6‰) is still lower than in the Chukchi Sea and the continental slope area (~32.5‰). The salinity of the Beaufort Sea is ~31‰. At 100 m, except in the Beaufort Sea area (<32‰), the salinity in the Western Arctic is ~32.7‰. At 150 m, the salinity of Beaufort Sea area (~32‰) is slightly lower than other areas characterized by salinities of 33‰ to 34‰. The salinity distribution pattern at 200 m is similar to that at 150 m, decreasing from ~34.5‰ in the basin area towards the Beaufort Sea area to ~33‰. The reversed salinity distribution pattern through depth indicates the influence of Atlantic water at intermediate and subsurface depths.

A clear characteristic appears in the Alaskan coastal area around 70°N. At all depths, the water temperature in this area is higher, and the salinity is lower than the surrounding ocean. This indicates the influence of warm, fresh water from the land (e.g., the Mackenzie River). The surface water in the high latitude Arctic is characterized by cold fresh melt water, and the subsurface water is influenced by warm saline Atlantic water.

2 Materials and methods

We collected 32 surface sediment samples (0–2 cm) from box cores, multi-cores and gravity cores recovered during the first and second Chinese National Arctic Research Expeditions (Table 1). Those samples were taken from the Chukchi Sea, the Beaufort Sea and the Canadian Basin, covering the latitudes 67° to 80°N, and longitude 146° to 172°W in the Western Arctic Ocean[24–25].

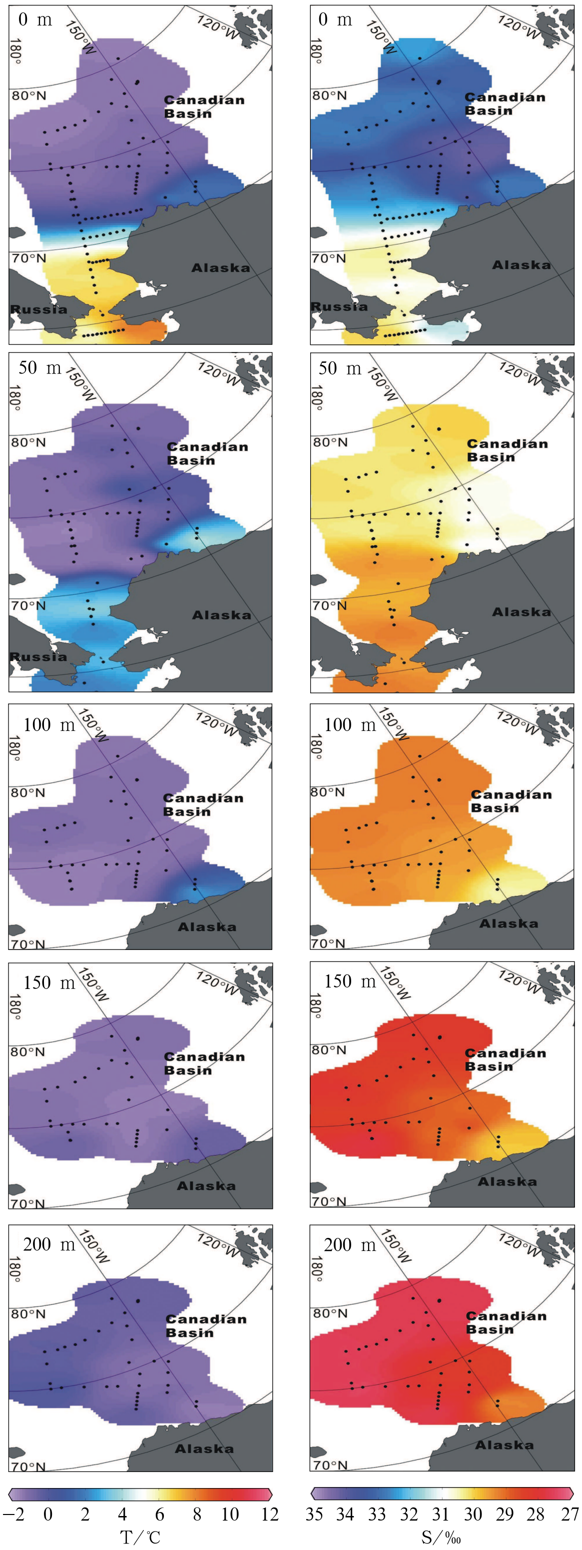

Figure 2 Water temperature (℃) and salinity (‰) at different depths in the Western Arctic Ocean, surveyed during the second Chinese National Arctic Research Expedition. The black dots denote the hydrological sites from this study.

Table 1 Location and water depth of the surface sediment samples from the Western Arctic Ocean[24−25]

Site	Longitude	Latitude	Water depth/m	Coring device
R03A	169°0′0″W	68°0′0″N	51	B
R06	169°0′0″W	69°29′43″N	53	B
R11	169°39′54″W	72°0′50″N	55	G
R15A	168°59′26″W	73°59′53″N	175	B
C11	167°59′3″W	71°39′51″N	48	B
C13	165°59′51″W	71°36′51″N	38	B
C15	164°0′46″W	71°34′45″N	43	B
C16	163°0′52″W	71°32′51″N	57	M
C17	162°2′1″W	71°29′21″N	57	B
P11	169°59′37″W	75°0′24″N	167	B
P21	167°21′38″W	77°22′44″N	562	B
P22	164°55′59″W	77°23′43″N	320	B
P23	162°31′5″W	77°31′40″N	2200	B
P24	158°43′16″W	77°48′38″N	1890	M
P27	156°0′22″W	75°29′33″N	3050	M
CNIS7	149°6′55″W	78°23′14″N	3850	B
IS10	151°50′49″W	79°17′ 36″N	3800	B
B11	156°19′54″W	73°59′42″N	3500	G
B77	152° 22′28″W	77° 31′10″N	3800	B
B78	147°1′41″W	78°28′43″N	3850	G
B80A	146°44′16″ W	80°13′25″N	3750	M
M01	169°0′46″W	77°17′56″N	1456	B
M03	171°55′52″W	76°32′13″N	2300	B
M07A	171°56′35″W	75°0′3″N	388	B
S11	159°0′14″W	72°29′24″N	40	B
S16	157°9′50″W	73°35′28″N	2800	B
S26	152°40′0″W	73°0′0″N	3000	B
P6700	169°58′38″W	67°0′17″N	47	B
P7100	169°59′28″W	70°59′17″N	40	B
P7230	168°38′10″W	72°29′33″N	54	B
P5	157°21′4″W	73°27′12″N	2600	M
P7	161°7′17″W	75°4′55″N	1700	M

Notes: B = box corer, M = multi corer and G = gravity corer.

The Chukchi Sea surface sediments were dark gray to black silty clays and rich in organic carbon due to high biological productivity and high sedimentation rates at these sites[24−25]. However, there were low abundances of the planktonic foraminifera *N. pachyderma* in the samples. This is likely due to the dilution of other materials in this area, or alternatively the shallow water depth of the Chukchi Sea may not be a favorable environment for this species. In the deep sea area of the Chukchi Plateau, the Northwind Ridge, the Beaufort Sea and the Canadian Basin, the surface sediments are mainly brownish mud, and rich in *N. pachyderma*.

The sediments were dried at 50 ℃, and wet–sieved through a 63 μm mesh. The >63 μm fraction was then dried and sieved through a 154 μm mesh. 20–25 specimens of the planktonic foraminifera *Neogloboquadrina pachyderma* were picked from the 154 to 250 μm size fraction. The shells were cleaned by ultrasonic agitation. The stable isotopes of δ^{18}O and δ^{13}C were analyzed using a Finnigan MAT 252 mass spectrometer. The results are expressed to the PDB standard. The standard errors of the measurements were ±0.08‰ for δ^{18}O and ±0.06‰ for δ^{13}C. All the sample preparation and analyses were carried out in the State Key Laboratory of Marine Geology, Tongji University, China.

3 Results

The δ^{18}O distribution pattern from *N. pachyderma* in the Western Arctic Ocean can be divided into three areas (Figure 3):

(a) The Chukchi continental shelf area had the heaviest values up to 4.6‰. This site is lacated close to the Bering Strait. In the central Chukchi sea the δ^{18}O was relatively lighter (<2.0‰).

(b) In the Chukchi Sea continental slope area, values were up to 2‰ to 3.5‰ from the area between 71.5° and 73°N.

(c) Lighter values of <2‰ were found in the Chukchi Plateau, Northwind Ridge and Canadian Basin area.

The most depleted δ^{13}C from *N. pachyderma* were found in the central/east Chukchi Sea with values ranging between 0.4‰ and 0.6‰. In the west and north Chukchi Sea, and in the sea ice covered Canadian Basin, the Chukchi Plateau and the Northwind Ridge area, relatively heavier δ^{13}C from *N. pachyderma* were observed ranging from 0.8‰ to 1.1‰.

4 Discussion

4.1 Age of sediments

The age of the sediments is a key issue in the interpretation of our data. The sedimentation rates vary in different areas, thus even the top 2 cm of sediments can represent deposition from different ages. However, if the sediments are from the Holocene, the variation of the isotope is minimal[9]. The Holocene sedimentation rate in the central Arctic basin is between 0.5 and 1 cm·(ka)$^{-1}$, and increases towards the continental margins to 5 to >10 cm·(ka)$^{-1}$[26]. The Chukchi Sea is characterized by a high sedimentation rate due to the high input of terrigeneous material and bioproductivity responding to seasonal open water and high nutrient supply from the Pacific Ocean[27–29]. In the area of Chukchi Plateau, Northwind Ridge and Canadian Basin, most of the surface sediments are characterized by brownish color and relatively high abundance in *N. pachyderma*, also suggesting Holocene deposition. Additional AMS^{14}C dating of core M03 (Figure 1) yields an age of 7–8 ka BP from the top 2 cm[30]. Although more datings from different regions are needed, the ages of the surface sediments in our study are likely to be within the Holocene.

4.2 Isotopic signatures of *N. pachyderma* as paleoceanographic proxies in the Arctic Ocean

N.pachyderma is a typical pycnocline planktonic foraminifera species. In the Arctic Ocean, the *N. pachyderma* calcifies at variable depths that range from the mixed surface layer down to a few hundred meters[8,10,31]. The maximum abundances of *N. pachyderma* are associated with the chlorophyll maximum in the surface from ~20 to 80 m[8]. It is generally thought to inhabit the water column between 50 and 200 m[8,17], although this varies regionally. At the Fram Strait, the depth distribution of *N. pachyderma* suggests a preference of the Atlantic water underlying the cold polar surface water between 50 and 200 m[32]. In the outer Laptev and Barents Seas, the maximum abundance of living *N. pachyderma* was between 50 and 100 m depth[12]. In the Nansen Basin, a latitudinal variation south of 83°N was found. The data suggest that *N. pachyderma* prefers water below the pycnocline at ~100 m. North of 83°N maximum abundance occurred in the upper 50 m[17]. Other investigations show that the habitat of *N. pachyderma* changes from ~150 m in the south to ~80 m in the north, but the calcification depth varies between 100 and 200 m[10].

In the North Atlantic Ocean, the heavier/larger specimens calcify towards the colder, saline layer, and are thus characterized by heavy isotopic compositions, and vice versa[33–34]. In contrast, in the Western Arctic Ocean, a reverse linear relationship between shell weight/size and the δ^{18}O content has been observed[31]. This may reflect the increasing temperature gradient from the cold surface mixed layer to the top of the warm intermediate Atlantic waters (150–200 m) where large specimens calcify. Thus, according to the species habitat, its isotopic signature reflects the water properties of various depths in different regions rather than simply surface water.

4.3 Implications of δ^{18}O in *N. pachyderma*

The δ^{18}O of planktonic foraminifera documents the δ^{18}O of the seawater, and also changes in water temperature and salinity[35–36]. The distribution pattern of δ^{18}O from *N. pachyderma* in the Western Arctic Ocean reflects the changes in the water environment.

According to the δ^{18}O and water temperature relationship, changes of 1℃ water temperature corresponds to a 0.26‰ change in the δ^{18}O of the foraminifera[35]. But the relationship between δ^{18}O and salinity varies in different areas. In the Norwegian Sea and Eastern Arctic Ocean, regression coefficients of 0.61‰ and 0.73‰ δ^{18}O per‰ salinity have been reported, respectively[37–38]. In the Eurasian Basin, a coefficient of 0.79 is calculated for the Arctic surface waters, thus a 1.00‰ change in seawater δ^{18}O is equivalent to about a 1.27‰ salinity change[9]. Meanwhile, the δ^{18}O is also influenced by the fresh water characterized by depleted δ^{18}O. The circum-Arctic meteoric water (precipitation and river runoff) carries a δ^{18}O signature of ∼–20‰[39−41], and the sea ice melt water ∼–2‰[42−43].

The water temperature in the shallow (∼50 m) Chukchi Sea shows a strong gradient decreasing from the Bering Strait to the Chukchi Sea shelf margin at about 71° to 72°N (Figure 2). However, the latitudinal distribution pattern of δ^{18}O from *N. pachyderma* does not totally reflect a temperature gradient. It appears to follow the current flow and mirror the mixing of different water masses. Following the AC in the western Chukchi Sea, the δ^{18}O values from *N. pachyderma* decrease from 4.66‰ (P6700) towards ∼3.4‰ (R11 & P7230) at the continental slope close to Herald Canyon. This is the main path of AC water entering the Arctic Ocean. Using the temperature factor (a 1℃ increase = a 0.26‰ change in δ^{18}O), the δ^{18}O difference could be explained by a 5℃ of water temperature change. This generally agrees with the surface temperature gradient between the core sites, and the salinity differences between the sites are minor (Figure 2). The sites in the central Chukchi Sea are bathed in the BSSW and lie more to the east in ACC water, which carries a considerable amount of fresh water from the land[44]. Thus, the light δ^{18}O values in the central and northeast Chukchi Sea may bear the signal of the freshwater components in the currents. In the Chukchi Sea continental margin area, from the Herald Canyon eastward, the generally decreasing δ^{18}O may be related to the mixing of the AC water with the BSSW and ACC Water. At the shallower site S11 (∼159°W), the δ^{18}O may still bear the signal of AC, which mirrors its eastward extension.

North of the Chukchi Sea continental margin, in an area of permanent sea ice cover[45], the water temperature and salinity are uniform at various depths. It is only slightly fresher and warmer close to the Beaufort Sea (Figure 2). The δ^{18}O values are generally uniform decreasing from the continental margin towards the central Arctic basin (Figure 3). The water temperature and salinity changes from the shelf area to the high Arctic basin cannot explain the changes in δ^{18}O from *N. pachyderma*. This pattern is in agreement with the trend found in the Eastern Arctic Ocean[9]. The heaviest δ^{18}O in the southern Nansen Basin is interpreted to reflect the inflow of

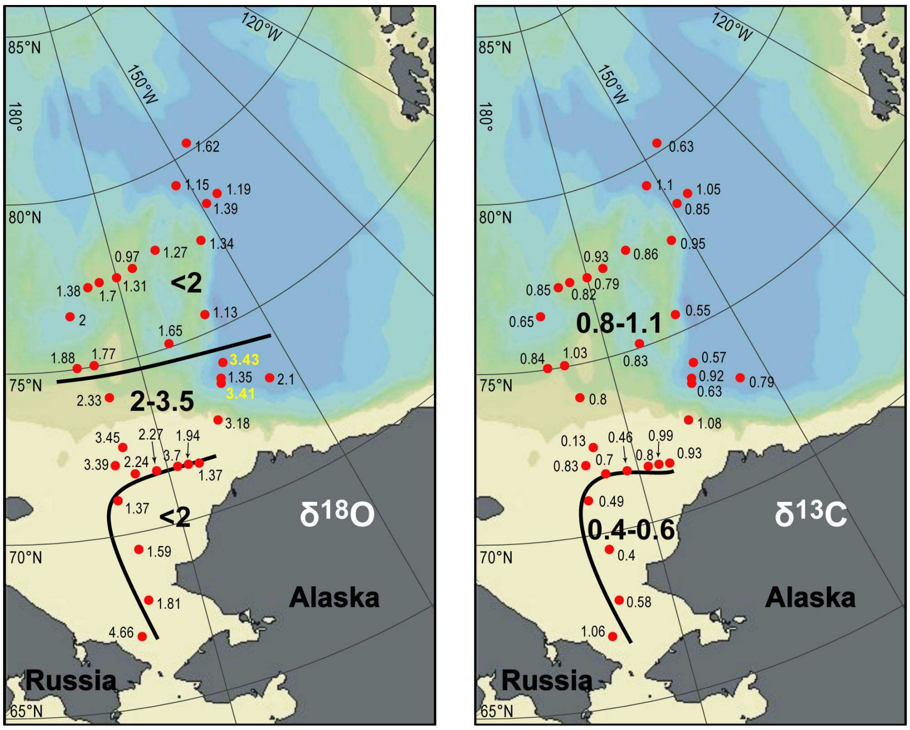

Figure 3 The δ^{18}O and δ^{13}C(‰) from *N. pachyderma* taken from surface sediments in the Western Arctic Ocean. Ambiguous heavy δ^{18}O values at sites B11 and P5 are highlighted in yellow.

Atlantic water at a habitat depth of 50–200 m (for *N. pachyderma*). The decreasing trend towards the central Arctic basin suggests a habitat change of *N. pachyderma* as it migrates from deeper layers to shallower fresh water depth with isotopically lighter δ^{18}O[9]. Such habitat change was observed in the southern Nansen Basin[17]. However, a recent plankton tow investigation in the Makarov Basin (88.4°N, 176.6°W) during the fourth Chinese National Arctic Research Expedition (summer 2010) is not in agreement with the habitat migration. The plankton tow showed that the maximum abundance of *N. pachyderma* occurred between 100 to 150 m (Wang R J, et al., unpubl. data). Although this plankton tow is not necessarily representative of the entire Arctic basin, it may suggest that the light δ^{18}O signal actually comes from different water sources with a lighter δ^{18}O signature. The large amount of fresh water in the Arctic basin is the most likely reason for this. In the Canadian Basin, the Beaufort Gyre keeps fresh water from the Pacific Ocean (inflow from the Bering Strait) and river runoff, which dilutes the seawater δ^{18}O in the surface ocean[41,46–48]

Heavy values of δ^{18}O from deep sites southeast of Northwind Ridge (e.g., ~3.4‰, B11 and P5, Figure 3) are ambiguous. They are much heavier than the adjacent sites (1.35‰ and 2.1‰ at S16 and S26, respectively). The lithological description of the surface sediments B11 and P5 were grayish to dark grayish mud, which is different from the brownish mud in other deep sea surface sediment[24–25]. The grayish sediments are possibly from a glacial/deglacial deposition characterized by heavy δ^{18}O values[49]. Additional datings are needed for better age control of the sediments.

4.4 Implications of δ^{13}C in *N. pachyderma*

Heavy δ^{13}C values are normally interpreted as good ventilation of surface waters[50]. In the central Arctic, the permanent sea ice cover prevents the gas exchange between ocean and atmosphere, thus ventilation is very limited. In contrast, ventilation mainly occurs in seasonally ice free areas, such as the shelf areas. However, our data show an inverse pattern that lighter δ^{13}C values occur in the central Chukchi Sea whereas heavier δ^{13}C values in the central Arctic. Thus, ventilation itself may not explain the δ^{13}C distribution pattern in the Western Arctic Ocean.

Besides ventilation, biological productivity plays a major role in the carbon isotopic fractionation and the δ^{13}C can also indicate nutrient consumption[51]. The carbon assimilation by primary productivity and export to the deep ocean preferentially takes ^{12}C, and thus ^{13}C is enriched in the surface waters. This effect results in heavy δ^{13}C in high primary productivity areas and light δ^{13}C in low productivity area. Satellite observations[52] indicate that extensive phytoplankton blooms occur during the summer in the Chukchi Sea and coastal Beaufort Sea. The seasonal variation of ice cover is the dominant factor as the ice-edge blooms follows the northward retreating marginal ice zones and in the central Arctic basin primary productivity is limited due to the permanent sea ice cover. In the west Chukchi Sea, along the AC, productivity is higher compared to the east Chukchi Sea, as a response of the high nutrient content of Anadyr water. More detailed *in-situ* observations of biomass distribution indicate other areas in the northeast Chukchi Sea also have high productivity[53]. This is also in agreement with the high opal and organic carbon content in the surface sediments from the corresponding high productivity areas[54]. Similar to the δ^{18}O distribution, heavy δ^{13}C values in the western Chukchi Sea correspond to the path of the AC, and in the northeastern Chukchi Sea with high bioproductivity. This area extends to the Chukchi Sea continental margin. In the central/eastern Chukchi Sea, sites with light δ^{13}C values are bathed in the BSSW and ACC. The differences in δ^{13}C values between the central/eastern and western/northeastern Chukchi Sea may result from the nutrient consumption and primary productivity in the different water masses.

The δ^{13}C of planktonic foraminifera is assumed to record the δ^{13}C signal of the surface water they live in. The ACC in the east Chukchi Sea carries considerable amount of fresh water. The riverine dissolved inorganic carbon (DIC) is usually depleted in ^{13}C, with δ^{13}C values of –5‰~–10‰[9,55]. We assume that the light δ^{13}C in *N. pachyderma* from the central and east Chukchi Sea also reflect the fresh water signal from the ACC.

North of the Chukchi continental margin, in an area with intensive sea ice cover, the ventilation and bioproductivity is limited. The heavy values (0.8‰ to 1.1‰) in the Canadian Basin, the Chukchi Plateau and the Northwind Ridge area are in agreement with a former investigation in the central Arctic basin[9]. This was interpreted as the transportation of well ventilated water from the shelf areas to the central Arctic basin. The light δ^{13}C at the Fram Strait and southern Nansen Basin were related to the intrusion of Atlantic water[9]. Although with high amount of riverine input, the Pacific source contributes the major part of fresh water in the Canadian Basin[48], which also points to the importance of the Pacific water to the Arctic Ocean. Obviously, one of the well ventilated water sources is from the Chukchi Sea with the inflow of Pacific water and the contribution of Pacific carbon isotope signal, possibly primarily from the AC, being of great importance. Other potential sources, such as the circum Arctic shelf area, are yet difficult to define, due to the lack of surface water DIC and *N. pachyderma* δ^{13}C information from these areas.

4.5 Limitations of this study

In this study we have tried to establish the relationship between the water properties and the δ^{18}O and δ^{13}C from *N. pachyderma*. However, due to the lack of seawater δ^{18}O and δ^{13}C of DIC measurements, our analysis is difficult. Moreover, in response to the rapid climate warming in recent years, the meltwater input by sea ice and ice sheet melting has strongly increased, as well as the river runoff. All these contribute to changes in the structure of the water column and modify the bioproductivity regime of the Arctic Ocean. The δ^{18}O and δ^{13}C from *N. pachyderma* in the surface sediment does not document these recent environmental changes. Thus error may occur during the relevance analysis and we cannot quantify these at present.

5 Conclusions

The stable isotopes of δ^{18}O and δ^{13}C from the planktonic foraminifera Neogloboquadrina pachyderma were analyzed from 32 surface sediments retrieved from the Western Arctic Ocean. The distribution of δ^{18}O in the Chukchi Sea reflects different water masses entering from the Pacific Ocean. The depleted δ^{18}O signal in the central and eastern Chukchi Sea may be from the fresh water of the ACC and BSSW, whereas the heavier δ^{18}O carries the signal of the AC. Depleted δ^{18}O values from the Chukchi Plateau, Northwind Ridge and Canadian Basin may reflect the surface freshwater in the high latitudes Arctic basin.

The foraminiferal δ^{13}C in the Chukchi Sea is also strongly related to different water masses in this region. Well ventilated Anadyr water and high bioproductivity result in heavier δ^{13}C values in the western Chukchi Sea. Lighter δ^{13}C in the central and eastern Chukchi Sea are related to the relatively lower bioproductivity and the freshwater component in the BSSW and ACC. Our data suggest that the Pacific Ocean water is one of the major components of the well ventilated water in the central Arctic Ocean.

Acknowledgments This work is funded by the National Basic Research Program of China (Grant no. G2007CB815903), the National Natural Science Foundation of China (Grant nos. 41030859 and 40321603), the China Program for International Polar Year 2007–2008 and the China Geological Survey Project (Grant no. H[2011]01–14–04). This work was part of the project "First Chinese National Arctic Research Expedition" and "Second Chinese National Arctic Research Expedition" supported by the Ministry of Finance of China and organized by the Chinese Arctic and Antarctic Administration (CAA), SOA. The participants in the joint work are from the institutions PRIC, FIO, SIO, Tongji University, etc. We thank the cruise members of the first and second Chinese National Arctic Research Expeditions, samples taken by Chen Ronghua, Chen Zhenbo, Gao Aiguo, Chen Jianfang, etc. and provided by the Polar Sediment Repository of Polar Research Institute of China (PRIC); Zhao Jinping, Jiao Yutian and Gao Guoping from the FIO and Data-sharing Network of Earth System Science-Polar Regional Center (http://www.chinare.org.cn) for providing the hydrological data. Samples information and data issued by the Resource-sharing Platform of Polar Samples (http://birds.chinare.org.cn) maintained by PRIC and Chinese National Arctic & Antarctic Data Center (CN-NADC). Data issued by the Data-sharing Platform of Ploar Science (http://www.chinare.org.cn) maintained by PRIC.

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