SENIOR THESIS
School of Earth Sciences
The Ohio State University

Submitted in partial requirement of Bachelor of Science
Degree, Geological Sciences

Study of Core 92AR-P25 from the Northwind Ridge,
Central Arctic Ocean
By Kevin Crawford
Winter Quarter 2008

ADVISOR: Dr. Leonid Polyak

ACKNOWLEDGMENTS

TABLE OF CONTENTS

Abstract:

The Arctic Ocean is presently the least understood ocean in the world. The perennial sea ice that covers most of the Arctic has hindered exploration and interpretation of this last remaining portion of the Earth's surface. The geologic history of this ocean is not fully understood and needs to be studied in greater detail. The stratigraphic record in the Arctic is a topic of much debate, specifically when discussing ages and sedimentation rates. Various ways of age dating has shed new light on ages and sedimentation rates of the established stratigraphy. Proxies such as microfossils and isotope evidence are giving us new insights to the paleoceanography of the Arctic Ocean basin. Core 92AR-P25 from the Northwind Ridge shows correlation with the paleomagnetic time scale and agreement with the manganese color cycles proposed by Jakobsson et al, (2000). The correlation of the core, shows that many cores throughout the Central Arctic Ocean can be similarly correlated, allowing us to form a paleoceanography history of the Arctic Ocean.

Introduction:

The Artic Ocean is an area that is not yet fully understood from a geological perspective. It is difficult to do research in the Arctic because of sea ice, deep water depths and the difficulty in working in the moving sea ice. With global warming, the retreating sea ice is exposing more of the Arctic area and making research possible, which is needed to predict the conditions that may arise as global warming progresses.

The Arctic Ocean is a small ocean that is almost entirely landlocked. It is constrained by the broad continental shelves off the coasts of Alaska, Canada, Greenland, northern Europe and Russia. The physiographic setting of the shelves make up 52.9% of

the Arctic, which is an extremely high percentage compared to the average of 9.1% to 17.7% of continental shelves for the rest of the world's oceans (Jakobsson, 2002). The second largest physiographic setting of the Arctic Ocean is the ridges that divide the abyssal plains of the Arctic Ocean. This is in contrast to the rest of the world's oceans where the abyssal plains usually occupy the largest part of the oceans (Jakobsson, 2002).

The Fram Strait is the only deep water access point to the Atlantic Ocean and to the global deep-sea circulation. It is located between Greenland and northwestern Svalbard at the northern tip of the Atlantic Ocean and is important for the thermohaline circulation of the global ocean.

The Arctic Ocean is presently going through an intense period of study; much like the period in the 1950's when the Atlantic, Pacific and Indian oceans were initially mapped in detail. Geophysical data such as seismic reflection and refraction data are scarce for the Arctic Ocean basin and large areas have not yet been surveyed. The available cores are limited and have mostly been extracted from the peripheral areas of the continental shelves and ridges of the Arctic Ocean due to the harsh working conditions. Few, if any cores are from the abyssal plains in the deep ocean basins (Backman et al, 2004).

The cores that are available are typically 10m or less in length and have few biostratigraphically useful calcareous and siliceous microfossils (Backman et al., 2004), which makes the paleoceanography difficult to interpret. The few recently collected cores show a stratigraphy that seems to correspond to that of other cores from the central Arctic Ocean that have been previously studied (Clark et al, 1980). However new evidence seems to contradict the ages of the layers, and consequently, the sedimentation

rates that were originally proposed. The area of the Arctic Ocean basin that is covered by sea ice shows evidence of unusual sedimentation patterns; fine-grained sediments exhibit low accumulation rates while faster accumulation occurs for the larger ice rafted debris (IRD). These cycles of sedimentation offer interpretations of past climates and a record of the retreat and advance of sea ice and surrounding continental ice sheets. The use of microfossils also gives us a record of the past climate and sea-ice extent.

The abyssal portion of the Arctic Ocean is divided into two smaller basins; the Amerasian and the Eurasian. The Amerasian Basin is bounded by the Lomonosov Ridge, the shelves of Alaska, the Canadian Archipelago and eastern Siberia. It is split into two halves by the Alpha-Mendeleev Ridge, which separates the Canadian and Makarov Basins.

The Eurasian Basin is bounded by the Lomonosov Ridge, western Siberia, northern Europe and Northeastern Greenland. The Gakkel Ridge splits the Eurasia Basin into two smaller basins; the Amundsen and Nansen. The Gakkel Ridge is the northernmost section of the Mid-Atlantic spreading zone.

The Arctic Ocean receives sediment from some of the world's largest rivers; the Yenisey, Lena, and Ob Rivers. Combined, these rivers have a catchment area (8060×10^3 km^2) almost equal to the entire area of the Arctic Ocean (9541×10^3 km^2) (Jakobsson, 2002). Large riverine sediment input could be one explanation for the unusually large continental shelves and rises in the Arctic Ocean. This small basin, enclosed by large landmasses, has remained relatively unchanged since its opening in the Early Cretaceous (Figure 1).

Purpose of study:

Correlating between cores across the Arctic Ocean is an important step in understanding the paleoclimate of the Arctic Ocean and the effects of glacial/interglacial periods on the climate of the planet as a whole. Separating the local versus regional conditions will give a better picture of the way the sea ice has reacted to warm periods in the past. This can help us predict the way the Arctic may react to the current global warming episode. Developing methods to accurately date the sediments in a core will help us correlate cores taken anywhere within the Arctic Ocean. A multidisciplinary approach has shown surprisingly good correlation between some cores in the Amerasian basin of the Arctic Ocean.

Paleomagnetic and lithostratigraphy have been the first methods used to try and tie ages to cores. The magnetic inclination reversal patterns of the cores have been correlated to the paleomagnetic time scale to give an absolute age however there are problems with this approach. If there are any unconformities in the core, the paleomagnetic signature will be incomplete and a reversal may be interpreted to be of younger age than it actually is. The paleomagnetic signature that was obtained from the early cores had a reversal that was interpreted to be the Bruhnes-Matuyama boundary (Clark et al, 1980). This reversal signature later was interpreted to be an excursion within the Bruhnes normal period (Jakobsson et al., 2000). Yet another interpretation suggests that this inclination pattern is controlled by diagenetic rather than geomagnetic processes (Xuah et al, 2008).

Clark et al (1980) described and identified 13 lithostratigraphic units in 580 short cores collected from throughout the central Arctic Ocean from Ice Island T-3 over the

course of its drift from 1952 through 1974. These units were correlated between cores on the basis of alternating layers of silty, gray and arenaceous, brown lutites with scattered layers of carbonate-rich, pinkish-white layers.

The silty, gray lutites are smaller in size and believed to represent glacial intervals when the ice pack was heaviest and biological activity was lowest. These lutites are interpreted to be deposited under heavy sea ice due to the low sedimentation rates and grain size of the material.

The arenaceous, brown lutites are more biologically rich and have a higher sand content. These are believed to be deposited at times of low or absent ice cover because the lack of sea ice promotes biological activity and allows for icebergs to break off of the surrounding continental ice sheets. In this area icebergs are believed to be from the North American Laurentide ice sheet, which would drop IRDs making the sediment coarser.

The carbonate rich, pinkish-white layers are important stratigraphic layers that are thought to have been deposited from icebergs that calved off of the Laurentide ice sheet. These carbonate clasts have been traced back to the Canadian Archipelago and believed to have circulated around the Amerasian Basin by atmospheric winds that drive the Beaufort gyre (Figure 2). These carbonate clasts can be tracked in a decreasing path that starts at the Northwind Ridge, across to the Alpha-Mendeleyev Ridge and on to the western side of the Lomonosov Ridge (Phillips and Grantz, 2001).

These layers and the content of sand-sized material were used to correlate units between cores taken "over several hundred thousand square kilometers and in several hundred cores" (Clark et al, 1980). These 13 units, designated A-M, are still in use today, but ages and sedimentation rates first proposed are under much debate due to

updated and more precise methods such as multiple C-14 dating, correlation to global

Marine Isotope Stages (MIS), and Amino Acid Racemization (AAR).

C-14 age dating has been around since 1949 and has greatly aided in assigning

absolute ages to samples tested. However, C-14 values are only valid for the last 30-40

thousand years based on the relative short half-life of C-14. Age dating from this method

is reliable, yet limited in the scope of reconstructing the history of the Arctic Ocean.

Furthermore, accurate interpretation of C-14 results is hindered by uncertainties with

reservoir mixing age in the Arctic Ocean.

The Marine Isotope stratigraphy is a record of the ratio of oxygen isotope 18 (O-

18) compared to oxygen isotope 16 (O-16). O-18 is considered to be "heavy" water and

resists evaporation while O-16 is considered to be light water and is evaporated first. As

ice sheets advance more and more water, globally, is locked up in the ice, mainly O-16,

which produces a concentration of O-18 left behind in the sea water. Marine animals

incorporate the surrounding ocean water into the calcareous shells they produce.

Therefore, by analyzing the ratio of O-18/O-16 isotopes in these shells, the paleoclimate

can be inferred based on the relative concentration of O-18 to O-16. This ratio is useful

to determine glacial from interglacial times.

Jakobsson et al (2000) first introduced the approach that manganese content and

corresponding color of sediment cycles in cores from the central Arctic Ocean correspond

to low-latitude MIS stages. The manganese content of the brown sediment is thought to

have been transported into the Arctic Ocean by way of drainage from Siberia. Siberia has

many peat bogs and boreal forests which have high manganese content. The cyclic

fashion of these dark brown sediments is thought to be a result of glacial-interglacial

periods. Drainage would be shut down during glacial periods and turned on during

interglacials. The brown units show not only high manganese concentrations, but contain

abundant microfossils and show signs of bioturbation.   The biological activity in the

brown manganese rich layers show that the water was oxygenated, which corresponds to

an interglacial when sea ice was thin or absent. This correlation can be extended to other

cores on the basis of the brown manganese rich units within them (Figure 3) (Jakobsson

et al, 2000).

Amino Acid Racemization (AAR) is a dating technique used to estimate the

relative ages of foraminifera in sediments. It is not as widely used as C-14 but it could

possibly enhance the dating procedures in the near future for several reasons. One is that

AAR is able to resolve older ages than C-14. Furthermore, AAR requires a smaller

sample size, which is less time consuming, more economical to test and allows for

selection of the best preserved individuals. AAR applied to Arctic planktonic

foraminifera appears to have a resolution with a margin of error of 10% (Kaufman et al,

in press).   Results from this work show that AAR correlates well to the C-14 dates,

paleomagnetic and MIS records. Because of these reasons, AAR procedures have the

potential to become the new standard in dating late Quaternary sediments in the future

(Kaufman et al, in press).

Each one of the preceding methods is not a stand alone method, as an individual

core can show regional differences in climate, sedimentation rates and amount of IRDs.

This causes problems when trying to correlate to other cores collected from around the

Arctic Ocean. By using all of these methods together, a more comprehensive picture of

the Arctic Ocean as a whole can be developed.

Procedures:

For this study I used core 92AR-P25 was obtained from a US Coast Guard ship on a United States Geological Survey expedition from the Northwind Ridge off the Chukchi continental shelf in the Amerasian Basin of the Arctic Ocean. A piston core recovered approximately 10m of sediment from the flank of the Northwind Ridge. Sampling was done every two centimeters from the top of the core down to 2m and then every four centimeters to a level of 4.8m. This allowed for a representative sampling of the core's characteristics. The samples were weighed, frozen and freeze dried to obtain dry sediment. The samples were then washed on a 63um sieve and dried. This procedure was used to obtain the sand percentage of the sample. Foraminifera were counted in the size fraction of greater than 150um. Both pelagic and benthic foraminifera were counted and divided by the dry weight of the sample to obtain the foraminifera per gram sediment used in figure 3. Paleomagnetic inclinations, Lightness (L*), carbon-14 ages (C-14) and Amino Acid Racemization (AAR) data in figure 3 were provided for this study by L. Polyak.

Data:

Figure 3 is a summary of data collected from core 92AR-P25. The combination of methods detailed in figure 3 shows the importance of using a multidisciplinary approach when describing a core from the Arctic Ocean. Superimposing the graphs onto a chart highlighting the alternating brown and gray units, along with the detrital carbonate rich layers, shows the peaks of both planktonic and benthic foraminifera match up with the brown layers extremely well. Benthic peaks all coincide with peaks from the planktonic foraminifera giving credence to the brown layers as interglacial/interstadial

11

periods dominated by higher biological productivity in the Arctic Ocean. The gray layers

(in white) shown in figure 3, correspond to low sand percentages, low biological

productivity and high lightness, indicating a glacial periods that were dominated by

heavy ice covering the Arctic Ocean and suppressing biological activity and the

deposition of larger grains. The magnetic inclination shows a pattern, that when

combined with the C-14 and AAR ages, can be placed correctly into the paleomagnetic

time scale. The major inclination drop corresponds to the level of 540 cm; this change in

inclination has been dated to occur within MIS7. The correct placement of the

paleomagnetic curve is imperative to determine the ages of the deeper core below the

level attainable by C-14 and AAR. Based on the ages represented by the core, the

sedimentation rate can be determined for the Northwind Ridge. Sedimentation rates for

the Northwind Ridge can be determined by dividing the core depth by the age determined

by C-14 and AAR. In this core the sedimentation rates are variable through time.

Present to 10,000 years ago, the sedimentation rates have averaged 0.01mm/yr. 10,000 to

20,000 years ago, the rate averages 0.1mm/yr. 20,000-30,000 years ago, the rate

averages 0.08mm/yr. 30,000 to 60,000 years ago, the rate averages 0.04mm/yr. 60,000

to 240,000 years ago the rate averages 0.08mm/yr. The overall average rate for this core

in the past 240,000 years is 0.02mm/yr.

Conclusion:

The intensive study of the Arctic Ocean is giving us a valuable look into the

glacials and interglacials of the past. New methods of dating and correlating information

between cores taken from around the Arctic Ocean provide a better picture of

paleoclimates. These paleoclimates are a window into the past, which can help us predict

the changes occurring from the current warming trend. A multidisciplinary approach is needed to correctly interpret the data recovered from cores. No one individual core will give us a complete picture, but in order to see this complete picture, we need to develop strategies to compare cores from across the ocean. As shown in my studies of core 92AR-P25, the use of paleomagnetic curves, alternating brown manganese-rich and grey layers, counts of planktonic foraminifera, and absolute age dating techniques can be combined to develop a picture that can be correlated across the central Arctic Ocean. New methods in determining lithologies, both absolute and relative age dating and chemical composition are beginning to reveal the picture in greater detail. Continuing studies will sharpen the picture even further.
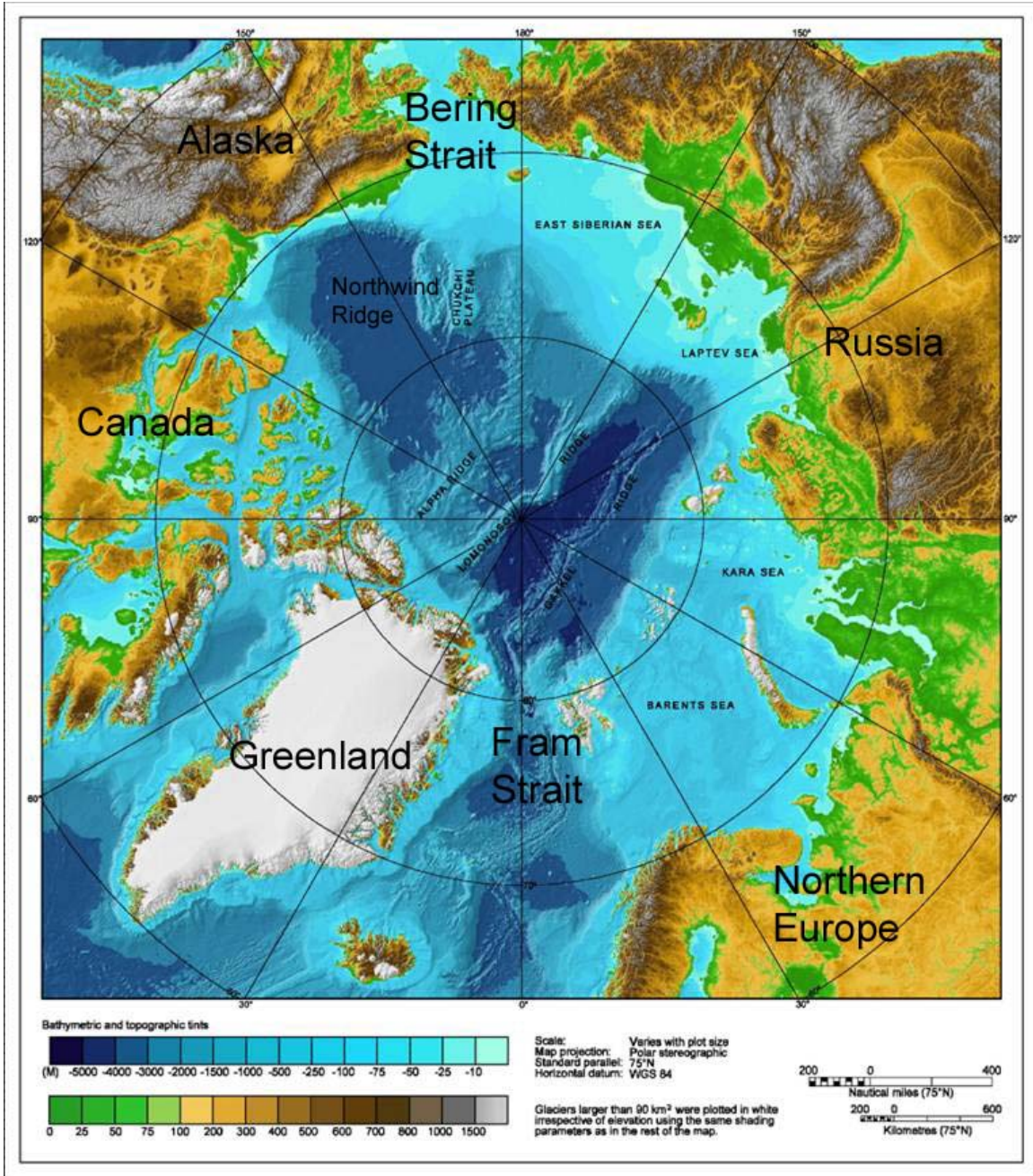
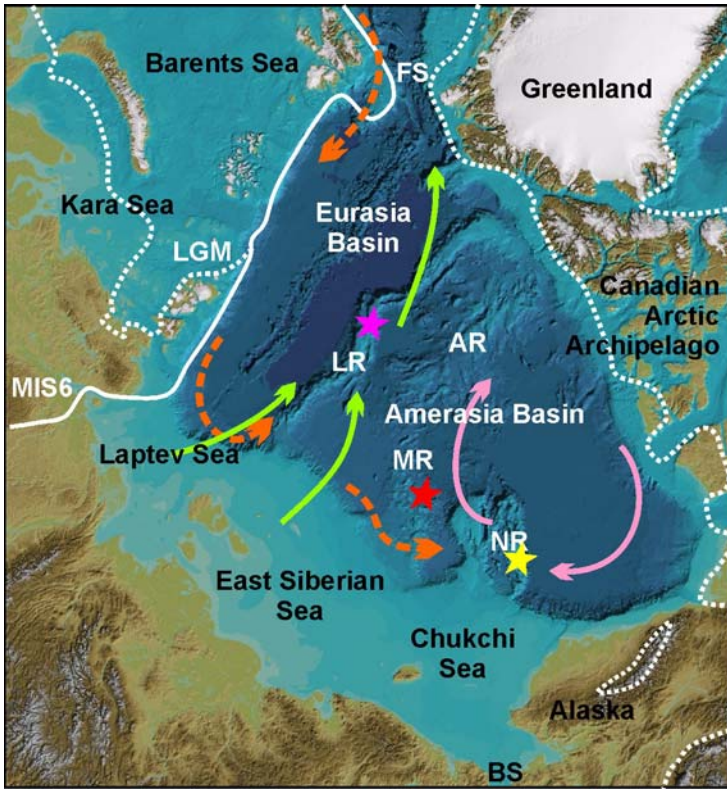Figure 1: Overview map of the Arctic Ocean

Figure 2: Close up map showing Northwind Ridge (NR), Mendeleyev Ridge (MR), Alpha Ridge (AR), Lomonosov Ridge (LR), stars show core locations, yellow star: 92AR-P25,red star: HLY0503-08JPC,purple star: ACEX drill location, Last Glacial Maximum (LGM) represented by the dotted white line, the extent of the European ice sheet represented by the solid white line, Tract of the Beaufort gyre represented by the pink arrows, Trans polar drift represented by the green arrows, and the deep water currents shown by the dashed orange arrows.
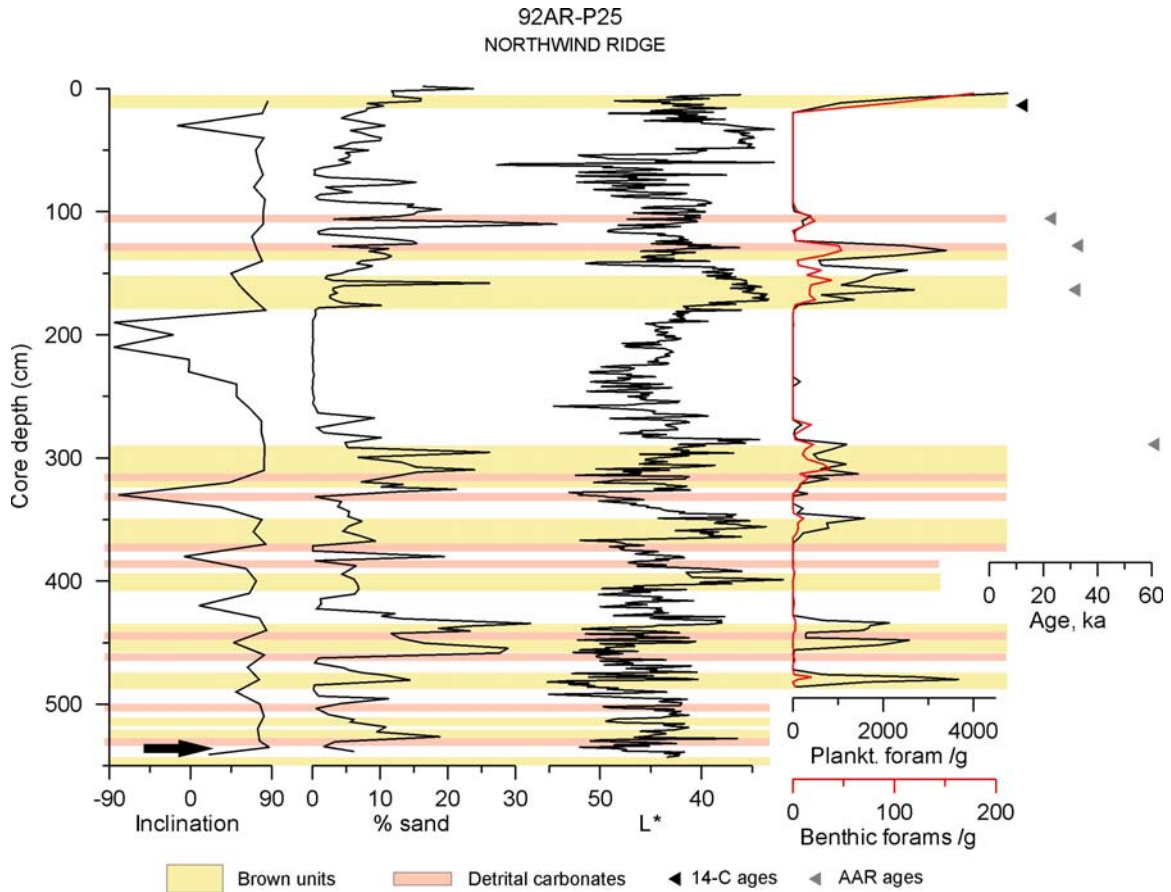
Figure 3: Brown units are in yellow, grey units are in white, detrital carbonates units are in pink. Black arrow shows magnetic reversal in MIS stage 7, ~240,000ka. Percent sand general pattern of low values in white layers and high values in yellow layers. Lightness shows general pattern of high lightness in white layers and low lightness in yellow layers. Planktonic and Benthic Foraminifera show good correlation with peaks in yellow layers.

REFERENCES CITED

Backman, J., Jakobsson, M., Lovlie, R., Polyak, L., Febo, L. A., 2004. Is the central Arctic Ocean a sediment starved basin? Quaternary Science Reviews. 23, pp 1435-1454

Bischof, J. F., Darby, D.A., 1997. Mid- to Late Pleistocene Ice Drift in the Western Arctic Ocean: Evidence for a Different Circulation in the Past. Science, vol 277, pp. 74-78.

Clark, D. L., Whitman, R. R., Morgan, K. A., Mackey, S. D., 1980. Stratigraphy and Glacial-Marine Sediments of the Amerasian Basin, Central Arctic Ocean. The Geological Society of America, Special Paper 181.

Jakobsson, M., 2002. Hypsometry and volume of the Arctic Ocean and its constituent seas. Geochemistry, Geophysics, Geosystems.

Jakobsson, M., Lovlie, R., Al-Hanbali, H., Arnold, E., Backman, J., Morth, M., 2000. Manganese and color cycles in Arctic Ocean sediments constrain Pleistocene chronology. Geology, vol 28; no. 1; pp 23-26.

Phillips, R.L., Grantz, A., 2001. Regional variations in provenance and abundance of ice-rafted clasts in Arctic Ocean sediments: implications for the configuration of late Quaternary oceanic and atmospheric circulation in the Arctic. Marine Geology 172, 91-115.

Polyak, L., Darby, D.A., Bischof, J. F., Jakobsson, M., 2007. Stratigraphic constraints on late Pleistocene glacial erosion and deglaciation of the Chukchi margin, Arctic Ocean. Quaternary Research 67, 234-245.

Polyak, L., Curry, W. B., Darby, D.A., Bischof, J. F., Cronin, T. M., 2004. Contrasting glacial/interglacial regimes in the western Arctic Ocean as exemplified by a sedimentary record from the Mendeleev Ridge. Palaeo, 203, pp 73-93.

Xuan, C., Channell, J., Polyak, L., 2008. Rock magnetic investigation of deep-sea sediments from the Mendeleev Ridge (Arctic Ocean). Abstract, Spring 2008 AGU Joint Assembly.