PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2015
Union College, Schenectady, NY

Dr. Robert J. Varga, Editor
Director, Keck Geology Consortium
Pomona College

Dr. Holli Frey
Symposium Convener
Union College

Carol Morgan
Keck Geology Consortium Administrative Assistant

Christina Kelly
Symposium Proceedings Layout & Design
Office of Communication & Marketing
Scripps College

Keck Geology Consortium
Geology Department, Pomona College
185 E. 6th St., Claremont, CA 91711
(909) 607-0651, keckgeology@pomona.edu, keckgeology.org

ISSN# 1528-7491

The Consortium Colleges The National Science Foundation ExxonMobil Corporation

KECK GEOLOGY CONSORTIUM
PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

ISSN# 1528-7491

April 2015

Robert J. Varga
Editor and Keck Director
Pomona College

Keck Geology Consortium
Pomona College
185 E 6th St., Claremont, CA 91711

Christina Kelly
Proceedings Layout & Design
Scripps College

Keck Geology Consortium Member Institutions:
Amherst College, Beloit College, Carleton College, Colgate University, The College of Wooster, The Colorado College, Franklin & Marshall College, Macalester College, Mt Holyoke College, Oberlin College, Pomona College, Smith College, Trinity University, Union College, Washington & Lee University, Wesleyan University, Whitman College, Williams College

2014-2015 PROJECTS

RESILIENCE OF ENDANGERED ACROPORA SP. CORALS IN BELIZE. WHY IS CORAL GARDENS REEF THRIVING?:
Faculty: LISA GREER, Washington & Lee University, HALARD LESCINSKY, Otterbein University, KARL WIRTH, Macalester College
Students: ZEBULON MARTIN, Otterbein University, JAMES BUSCH, Washington & Lee University, SHANNON DILLON, Colgate University, SARAH HOLMES, Beloit College, GABRIELA GARCIA, Oberlin College, SARAH BENDER, The College of Wooster, ERIN PEELING, Pennsylvania State University, GREGORY MAK, Trinity University, THOMAS HEROLD, The College of Wooster, ADELE IRWIN, Washington & Lee University, ILLIAN DECORTE, Macalester College

TECTONIC EVOLUTION OF THE CHUGACH-PRINCE WILLIAM TERRANE, SOUTH CENTRAL ALASKA:
Faculty: CAM DAVIDSON, Carleton College, JOHN GARVER Union College
Students: KAITLYN SUAREZ, Union College, WILLIAM GRIMM, Carleton College, RANIER LEMPERT, Amherst College, ELAINE YOUNG, Ohio Wesleyan University, FRANK MOLINEK, Carleton College, EILEEN ALEJOS, Union College

EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SW MONTANA: METASUPRACRUSTAL ROCKS OF THE RUBY RANGE
Faculty: TEKLA HARMS, Amherst College, JULIE BALDWIN, University of Montana
Students: BRIANNA BERG, University of Montana, AMAR MUKUNDA, Amherst College, REBECCA BLAND, Mt. Holyoke College, JACOB HUGHES, Western Kentucky University, LUIS RODRIGUEZ, Universidad de Puerto Rico-Mayaguez , MARIAH ARMENTA, University of Arizona, CLEMENTINE HAMELIN, Smith College

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1358987
ExxonMobil Corporation

GEOMORPHOLOGIC AND PALEOENVIRONMENTAL CHANGE IN GLACIER NATIONAL PARK, MONTANA:
Faculty: KELLY MACGREGOR, Macalester College, AMY MYRBO, LabCore, University of Minnesota
Students: ERIC STEPHENS, Macalester College, KARLY CLIPPINGER, Beloit College, ASHLEIGH, COVARRUBIAS, California State University-San Bernardino, GRAYSON CARLILE, Whitman College, MADISON ANDRES, Colorado College, EMILY DIENER, Macalester College

ANTARCTIC PLIOCENE AND LOWER PLEISTOCENE (GELASIAN) PALEOCLIMATE RECONSTRUCTED FROM OCEAN DRILLING PROGRAM WEDDELL SEA CORES:
Faculty: SUZANNE O'CONNELL, Wesleyan University
Students: JAMES HALL, Wesleyan University, CASSANDRE STIRPE, Vassar College, HALI ENGLERT, Macalester College

HOLOCENE CLIMATIC CHANGE AND ACTIVE TECTONICS IN THE PERUVIAN ANDES: IMPACTS ON GLACIERS AND LAKES:
Faculty: DON RODBELL & DAVID GILLIKIN, Union College
Students: NICHOLAS WEIDHAAS, Union College, ALIA PAYNE, Macalester College, JULIE DANIELS, Northern Illinois University

GEOLOGICAL HAZARDS, CLIMATE CHANGE, AND HUMAN/ECOSYSTEMS RESILIENCE IN THE ISLANDS OF THE FOUR MOUNTAINS, ALASKA
Faculty: KIRSTEN NICOLAYSEN, Whitman College
Students: LYDIA LOOPESKO, Whitman College, ANNE FULTON, Pomona College, THOMAS BARTLETT, Colgate University

CALIBRATING NATURAL BASALTIC LAVA FLOWS WITH LARGE-SCALE LAVA EXPERIMENTS:
Faculty: JEFF KARSON, Syracuse University, RICK HAZLETT, Pomona College
Students: MARY BROMFIELD, Syracuse University, NICHOLAS BROWNE, Pomona College, NELL DAVIS, Williams College, KELSA WARNER, The University of the South, CHRISTOPHER PELLAND, Lafayette College, WILLA ROWEN, Oberlin College

FIRE AND CATASTROPHIC FLOODING, FOURMILE CATCHMENT, FRONT RANGE, COLORADO:
Faculty: DAVID DETHIER, Williams College, WILLIAM. B. OUIMET, University of Connecticut, WILLIAM KASTE, The College of William and Mary
Students: GREGORY HARRIS, University of Connecticut, EDWARD ABRAHAMS, The College of William & Mary, CHARLES KAUFMAN, Carleton College, VICTOR MAJOR, Williams College, RACHEL SAMUELS, Washington & Lee University, MANEH KOTIKIAN, Mt. Holyoke College

SOPHOMORE PROJECT: **AQUATIC BIOGEOCHEMISTRY: TRACKING POLLUTION IN RIVER SYSTEMS**
Faculty: ANOUK VERHEYDEN-GILLIKIN, Union College
Students: CELINA BRIEVA, Mt. Holyoke College, SARA GUTIERREZ, University of California-Berkeley, ALESIA HUNTER, Beloit College, ANNY KELLY SAINVIL, Smith College, LARENZ STOREY, Union College, ANGEL TATE, Oberlin College

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1358987
ExxonMobil Corporation

Keck Geology Consortium: Projects 2014-2015
Short Contributions— Paleoclimate Reconstruction From Weddell Sea ODP Cores Project

ANTARCTIC PLIOCENE AND LOWER PLEISTOCENE (GELASIAN) PALEOCLIMATE RECONSTRUCTED FROM OCEAN DRILLING PROGRAM WEDDELL SEA CORES:
Faculty: SUZANNE O'CONNELL, Wesleyan University

XRF DERIVED CYCLICITY IN PLIOCENE AND PLEISTOCENE SEDIMENTS FROM ODP SITE 693, DRONNING MAUD LAND ANTARCTICA
JAMES HALL, Wesleyan University
Research Advisor: Suzanne OConnell

PLEISTOCENE FORAMINIFERA ASSEMBLAGES AS A PROXY FOR TEMPERATURE IN THE WEDDELL SEA, ODP SITE 693A
CASSANDRE STIRPE, Vassar College
Research Advisors: Suzanne O'Connell, Kirsten Menking

PROVENANCE OF WEDDELL SEA DROPSTONES: PETROGRAPHIC AND GEOCHEMICAL EVIDENCE
HALI ENGLERT, Macalester College
Research Advisors: Karl Wirth and Suzanne O'Connell

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1358987
ExxonMobil Corporation

Learning Science Through Research
Published by Keck Geology Consortium
Short Contributions
28th Annual Symposium Volume
25th April, 2015
ISBN: 1528-7491

PLEISTOCENE FORAMINIFERA ASSEMBLAGES AS A PROXY FOR TEMPERATURE IN THE WEDDELL SEA, ODP SITE 693A

CASSANDRE STIRPE, Vassar College
Research Advisors: Suzanne O'Connell, Kirsten Menking

ABSTRACT

Climate conditions in the Weddell Sea during the Pleistocene can be inferred from sediment cores by examining the abundance of foraminifera species and mineral fragments. In particular, *Neogloboquadrina incompta* is a useful temperature proxy and the abundance of terrigenous sediments is an indication of ice rafting. Using percent abundances enables correlation with other climate studies and with a global $\delta^{18}O$ isotope stack. The proxies examined indicate at least four oscillations between cold and warm conditions related to global glacial and interglacial stages.

INTRODUCTION

Foraminifera and ice-rafted debris (IRD) are important climate proxies because of the environmental requirements necessary for their existence. For IRD to appear in ocean sediments, there must be terrestrial erosion and ice sheets calving to release floes into the water. Furthermore, foraminifera species are often restricted to certain environments based largely on temperature, salinity, and water depth. Using these general rules, it is possible to infer climatic information from the prevalence of different foraminifera species and the quantity of IRD in sediments, and this study uses such guidelines in analysis of a Pleistocene sediment core.

The site used for this study is located in the southeastern Weddell Sea, off the coast of Antarctica, a little studied region. While many studies have focused on ice extent and climate change in the Arctic, far fewer have explored the high latitudes of the southern hemisphere, meaning that there is a greater understanding of the Greenland ice sheet and Arctic sea ice than there is of their Antarctic counterparts (Teitler et al., 2010). In particular, it is unclear how sensitive Antarctic ice sheets are to climatic drivers such as changes in insolation (McKay et al., 2012).

Poor understanding of the present also means that there are uncertainties about the past. Some models propose that global temperature changes caused Arctic and Antarctic ice to follow similar progressions over time while others theorize that ice extent and stability between the two hemispheres were out of phase with one another due to differing insolation (Raymo and Huybers, 2008). Some of the reason for such uncertainty lies in the fact that many records, such as Lisiecki and Raymo's (2005) $\delta^{18}O$ stack are biased toward the Atlantic and eastern Pacific, with less attention given to the southern hemisphere (Elderfield et al., 2012). Such biases in our understanding of global climate illustrate the need for further research in the Antarctic to gather data that could be correlated with Arctic records.

One time period for which such correlations may prove particularly illuminating is the Pleistocene, known for its glacial and interglacial intervals. It was during the Pleistocene in the past 800,000 years that glaciations changed from a 41,000 year period (Earth's obliquity) to a 100,000 year period, corresponding to Earth's eccentricity (Raymo and Huybers, 2008). The reasons for this shift are still unclear, particularly given that Earth's eccentricity is the weakest orbital parameter and that the mid-Pleistocene change in periodicity was not correlated with any known change in insolation (Clark, 2012).

The aim of this study is to examine foraminifera and mineral assemblages over a 5-meter Pleistocene section of core to see how they might reflect climate change over time. The data are expected to indicate sea surface warmth and ice cover in the Weddell Sea with periodicities potentially responding to insolation cycles. The hypothesis is that cooler intervals would see perennial sea ice coverage, while warmer intervals would harbor more life and contain IRD as a result of the breakup of ice sheets.

STUDY AREA

This study examines sediments from the Weddell Sea, off the coast of Antarctica. The sediments come from cores extracted by Ocean Drilling Program (ODP) Leg 113, Site 693A (70º49.892'S, 14º34.410'W) in a water depth of 2359 meters, on a northwest-facing slope of the continental margin. Sedimentation rates were low during the Pleistocene, measuring less than 10 meters per million years (Barker and Kennet et al., 1988). Hall (this volume) estimates sedimentation rates of 4-5 cm/1000 yr, while Grobe and Mackensen (1992) calculated rates of 2.9 cm/1000yr for interglacials and 0.3 cm/1000yr for glacials. The Weddell Sea has an area of around 2.8 million km^2 and experiences both permanent ice-cover at its southern end and seasonal sea ice elsewhere. The Weddell Sea is also the primary location of the production of Antarctic Bottom Water, a cold and high density water mass that underlies much of the world's oceans (Hogan, 2013). The similarity between today's environment in the Weddell Sea and conditions during climate oscillations in the Pleistocene is one of the questions behind this study.

METHODS

The data for this study come from sediment cores collected in 1987 by ODP Leg 113, at Site 693A. A *Polarstern* expedition collected a piston core at the same position, core PS1591, and data from analysis of that core (Grobe et al 1990; Grobe and Mackensen 1992) have been used to supplement data from Site 693A. Sediment samples used in this study were taken from core 2R in 2013 and 2014. At that time, cores were also scanned for whole core XRF measurements and magnetic susceptibility. High-resolution imaging with RGB data was also taken.

Sediment samples were washed and sieved into >500µm, 150-500µm, 63-150µm, and <63µm fractions, and allowed to dry before being weighed. This study examines the contents of the 150-500µm fraction with a focus on foraminifera. A total of 21 samples were studied, selected using data on percent coarse fraction (>150 µm) and XRF measurements of Ca/Fe to determine areas of interest (Fig. 1). The densest sampling occurred between 7 and 8 meters below sea-floor (mbsf) due to the greatest amount of variability in this interval. Each sample was split at least once, but may have been split as many as four times to achieve a final weight between 0.02g and 0.05g prior to counting. The two smallest samples fall below this range at 0.017g (from 6.83 mbsf), and one at only 0.005g (from 5.00 mbsf) due to a small 150-500µm size fraction.

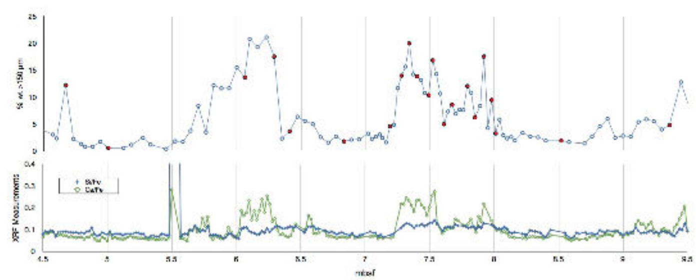

Figure 1. Graphs used to assist in selecting samples for counting. The percent weight >150µm (top) includes sample locations. Also shown are the Si/Fe and Ca/Fe ratios from whole core XRF measurements. Note how Ca/Fe correlates with weight % >150µm.

Analysis of each sample was performed by identifying and counting foraminifera specimens until a total of at least 500 individuals was reached. To help ensure accurate sampling, the picking tray was divided into 45 equal squares and a random number generator was used to select the order in which squares were examined. Upon reaching 500 individuals, the current square was completed. Four of the twenty-one samples fall well below the desired count of 500 330 individuals, 238 individuals, 91 individuals, and 9 individuals. In these cases, all foraminifera present in the sample were counted.

The counting and picking was performed under a binocular dissecting microscope with magnification 15 to 94.5x. Foraminifera identification was performed using a list of species found in sediments contained in the core catcher at nearby ODP Sites 690 and 689 on Maud Rise. The primary categories of classification were between *Neogloboquadrina pachyderma* (sinistral, which accounted for >90% of specimens), *Neogloboquadrina incompta* (dextral), benthic foraminifera (identified by test texture), foraminifera fragments (pieces too small to identify and consisting of at least two test chambers), and mineral grains (which were further divided into light and dark minerals). Any other items of interest such as shell fragments, echinoderm spines, or rare foraminifera species were noted. The numbers in all of these categories and their percent abundances constitute the majority of data for this study.

RESULTS

Core Description

The core section examined in the present study ranged from a depth of 4.67 mbsf to 9.36 mbsf, covering a total length of 4.69 meters and corresponding to sections of ODP Core 693A 2R2 through 2R5. The sediment is composed of silty and clayey mud, ranging from dark grayish brown to olive gray and containing foraminifera and scattered grains of sand (Barker and Kennet et al., 1988). Color changes appear to coincide with changes in the foraminifera content and occur in gradational shifts. Several dropstones occur throughout the core section.

Foraminifera

Of the foraminifera counted, 98.5% were planktic species and the remaining 1.5% were benthic species. The species *Neogloboquadrina pachyderma* (sinistral) was by far the most abundant, totaling 93% of the foraminifera counted. The other dominant planktic form was dextral *Neogloboquadrina incompta* (3.4%), which today is found in more temperate waters (Encyclopedia of Life). Comparing the ratios between these two species shows that the foraminiferal community changed over time, with some periods favoring *N. incompta* more than others (Fig. 2). The abundance of *N. pachyderma* ranged from 77.8% to 96.6%, with an average of 92.1%. The abundance of *N. incompta* ranged from 0% to 6.1%, with an average of 3.2%.

The total number of intact foraminifera was also compared to foraminifera fragments (composed of more than one test chamber) to study preservation (Fig. 2). The maximum ratio of complete forams to fragments was 3.8 and the minimum was 0.33, resulting in a tenfold difference from the best-preserved sample to the worst-preserved sample. The mean foraminiferafragment ratio was 1.8 to 1. There are three local maxima occurring at 6.29, 7.85, and 9.36 mbsf, and corresponding minima at 6.06, 7.19, and 8.52 mbsf.

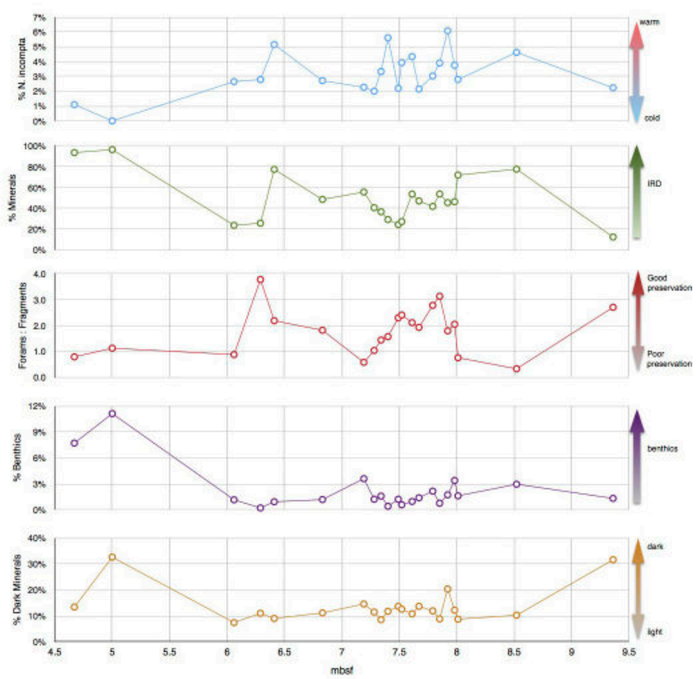

Figure 2. Results of sample counting, according to depth (mbsf). From top to bottom, % N. incompta, a temperature proxy indicating surface ocean conditions; % Mineral fragments, which provides information about ice-rafted debris. Other graphs include % benthic foraminifera, foram-to-fragment ratios, and % abundance of dark minerals (i.e. biotite, hornblende, garnet).

MINERAL FRAGMENTS

Mineral fragments were counted and their abundance analyzed as a percentage of total grains counted, with grains being the sum of foraminifera and minerals (Fig. 2). The highest percentage of mineral grains (96.7%, 5.00 mbsf) occurred in the smallest sample, and therefore may not be an accurate measure. The minimum value of 12.4% minerals (9.36 mbsf) occurred at the end of the core section studied. The average was 49.1%, with a standard deviation of 23.3%, indicating that there was considerable variability but that overall, the percentage of foraminifera and mineral grains was approximately equal.

The percent abundance of dark minerals (i.e. biotite, hornblende, garnet) out of the total mineral grains counted (Fig. 2) varied from 7.3% (6.06 mbsf) to 32.6% (5.00 mbsf) with an average of 13.5% and a standard deviation of 6.8%. The percent abundance of light minerals is an inverse of this. Light minerals made up an average of 86.5%, reflecting the predominance of quartz in the samples.

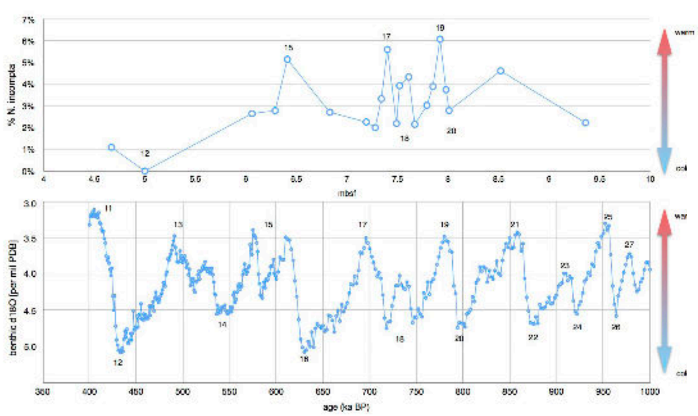

Figure 3. Correlation between this study (top) and the Lisiecki and Raymo (2005) global benthic δ18O stack (bottom). Marine isotope stages 11 through 17 are labeled on the δ18O curve, with proposed corresponding points on the graph of % N. incompta. The δ18O from 400 to 1000 kya were chosen for correlation based on estimated ages given by the Grobe et al. (1990) age model.

DISCUSSION

Age and Resolution

According to the age model presented in Grobe and Mackensen (1992) for the core PS1591, the sediments examined here, with a depth of 4.67 to 9.36 mbsf, should have ages ranging between approximately 450 ky and 1.5 My. According to the same model, between 6 and 8 mbsf, sedimentation rates were approximately 1 cm/ky. This would give a maximum resolution of 3000 years between samples. Deeper than 8 mbsf, sedimentation rates were lower and resolution is therefore poorer. Additional age correlation can be gained from comparison with the global $\delta^{18}O$ stack (Lisiecki and Raymo, 2005), placing the interval 6 to 8 mbsf between approximately 550 to 800 kyr old (Fig. 3).

Temperature

The percent abundance of *N. incompta* was used as a temperature proxy, with greater numbers of *N. incompta* corresponding to warmer temperatures. Correlation is limited between this study and Grobe and Mackensen (1992), due to different coring methods and different sampling densities (Fig. 4). The $\delta^{18}O$ and $\delta^{13}C$ values suggest potential correlations at some of the maxima and minima, but precise interpretation is difficult.

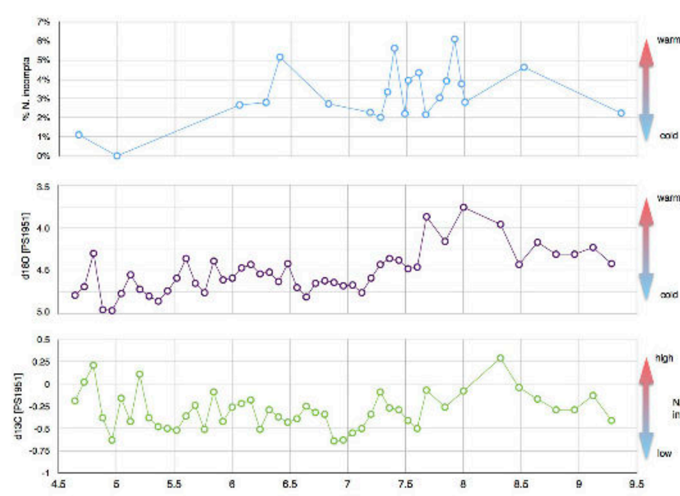

Figure 4. Comparison with data from Grobe and Mackensen (1992), core PS1591-1, on the same position as ODP Site 693A. Top graph is % N. incompta (this study). Middle and lower curves show δ18O and δ13C from PS1591, measured on planktic foraminifer N. pachyderma. Enrichment in 13C is characteristic of influx of NADW into the southern ocean, present during interglacials and suppressed during glacials.

According to this study, the % *N. incompta* indicates warm periods at 6.41, 7.40, 7.61, 7.92, and 8.52 mbsf (Fig. 2). The time interval between 6.41 and 7.40 mbsf may correspond to a 100-ky cycle, consistent with Pleistocene glacial/interglacial periods. The oscillations between 7.40 and 7.92 mbsf are more difficult to understand, perhaps influenced by shorter-period orbital cycles. Comparison with a global oxygen isotope stack (Fig. 3) reveals that these intervals may correspond to marine isotope stages (MIS) 17, 18, and 19 from 700-800 kya (Lisiecki and Raymo 2005). This is a period shortly after the mid-Pleistocene transition, when glacial oscillations changed from a periodicity of 41 to 100 kyr.

Terrigenous Sedimentation

The percent abundance of mineral grains follows the same trend as *N. incompta* for some intervals, and deviates from that pattern in others.

Between 9.5 and 8.52 mbsf, the mineral abundance increases along with temperature (Fig. 2), but this must be viewed with caution due to the low density of sampling in this range. The change in mineral abundance also follows inferred warmth between 7.28 to 6.06 mbsf. This corresponds well with the sedimentation model presented by Grobe and Mackensen (1992) in which increased warmth contributes to ice calving which carries sediment from the continental shelf out onto the slope. Elsewhere, the relationship between temperature and mineral deposition is more complex and does not align as clearly. From 8.01 to 7.92 mbsf, mineral deposition decreases with temperature. This inverse relationship could be a result of ice retreat further south, away from Site 693.

The percent abundance of dark mineral fragments appears to have an inverse relationship with temperature, with higher percentages of dark minerals occurring during cooler periods, and lower percentages occurring during the warm intervals. (The most significant exceptions are at the very beginning and end of the core section sampled, which are points that must be treated with caution due to their low sample size.) One possible explanation for this is that there is a relatively constant deposition of dark minerals, but that warmer periods see a greater deposition of quartz grains. It is also possible that ice rafting carries sediments from a different source area depending on temperature conditions.

CONCLUSIONS

The data indicate at least three transitions from glacial to interglacial conditions in the Antarctic, with two of those corresponding to MIS stages 20 to 19, and 18 to 17. Warmer interglacial conditions are indicated by a decrease in IRD and an increase in the foraminifera species *N. incompta*. These correspond to models suggesting reduced Antarctic sea ice coverage during Northern Hemisphere interglacial stages.

REFERENCES

Barker, P. F., Kennett, J. P., et al., 1988, Site 693 Proceedings of the ODP, Initial Reports, 113, p. 329-447.

Clark, P. U., 2012, Ice Sheets in Transition Science, v. 337, p. 656-658.

Elderfield, H., Ferretti, P., Greaves, M., Crowhurst, S., McCave, I. N., Hodell, D., and Piotrowski, A. M., 2012, Evolution of Ocean Temperature and Ice Volume Through the Mid-Pleistocene Climate Transition Science, v. 337, p. 704-709.

Grobe, H., Fütterer, D. K., and Spieβ, V., 1990, Oligocene to Quaternary sedimentation processes on the Antarctic continental margin, ODP Leg 113, Site 693 Proceedings of the Ocean Drilling Program, Scientific Results, 113, p. 121-131.

Grobe, H., and Mackensen, A., 1992, Late Quaternary climatic cycles as recorded in sediments from the Antarctic continental margin The Antarctic Paleoenvironment A perspective on Global Change, Antarctic Research Series, v. 56, p. 349-376.

Hogan, C., 2013, Weddell Sea, The Encyclopedia of Earth.

Retrieved from http//www.eoearth.org/view/article/157033 (accessed February 2015).

Lisiecki, L. E. , and Raymo, M. E., 2005, A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}O$ records Paleoceanography, v. 20, PA1003.

McKay, R., Naish, T., Powell, R., Barrett, P., Scherer, R., Talarico, F., Kyle, P., Monien, D., Kuhn, G., Jackolski, C., and Williams, T., 2012, Pleistocene variability of Antarctic Ice Sheet extent in the Ross Embayment Quaternary Science Reviews, v. 34, p. 93-112.

"*Neogloboquadrina incompta*." Encyclopedia of Life, available from http//eol.org/pages/2954367/ overview (accessed February 2015).

Raymo, M. E., and Huybers, P., 2008, Unlocking the mysteries of the ice ages Nature, v. 451, p. 284-285.

Teitler, L., Warnke, D. A., Venz, K. A., Hodell, D. A., Becquey, S., Gersonde, R., and Teitler, W., 2010, Determination of Antarctic Ice Sheet stability over the last ~500 ka through a study of iceberg-rafted debris Paleoceanography, v. 25, PA1202.