by Shackleton et al. (2000) from a core off Portugal using an analogous method for age model construction. This result confirms the similarity between the benthic oxygen isotope record and the temperature record of the Antarctic ice cores first documented by these authors.

Ice rafted debris (ird) is only present in small quantities, and was monitored here by counting quartz grains (as well as detrital carbonate) in the 90-150 micrometer size fraction. During every Greenland Stadial ird reached this subtropical location. The accumulation rate of ird is on average about 20 times higher in stadial than in interstadial. In general, the temporal pattern of ird accumulation resembles the pattern of magnetic susceptibility (indicating the finer grain component of ird) off the Portuguese coast.

Between stadial and interstadial SST as estimated by foraminiferal faunal analysis varied by about 3°C (a value that is supported by lower-resolution organic geochimical data). However during stadials in particular, faunal SST estimate are noisy suggesting that an important water mass boundary lay close to Site 1060 during Stadials.

Both the benthic δ13C values, which are consistently lighter during each stadial, and increased fragmentation of foraminifera (indicative of carbonate dissolution) in the stadials, indicate the replacement of the present NADW by southerly originating AABW within the North Atlantic during MIS3 at millennial scale resolution.

PP12C-05 1645h INVITED

Atmospheric CO2 and Deep-Water Formation in the Southern Ocean

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The Southern Ocean is thought to have a special role in the oceans biological pump because of the nitrate and phosphate that goes unutilized in its surface waters. Many authors have attributed the low levels of atmospheric CO2 during glacial periods to more efficient utilization of these nutrients by polar organisms. Here it is argued that the Southern Ocean sleuths at work on the glacial-interglacial CO2 problem have been pursuing the right suspect but have misunderstood his modus operandi, i.e. Southern Ocean nutrients are the key, but not because they are underutilized by organisms.

The Southern Oceans role in glacial-interglacial CO2 variations is best appreciated via the different ways that deep water is formed and circulated in the North Atlantic and Southern Ocean. The overturning associated with deep-water formation in the North Atlantic brings water from the deep ocean into contact with the biota of the upper ocean. The overturning associated with deep-water formation in the Southern Ocean generally does not. CO2 remineralized from organic particles in the productive North Atlantic system leaks out of the deep ocean via the unproductive Southern Ocean system. This means that an on/off cycle in the production of Southern deep water can release, or not release, large amounts of CO2 from the deep ocean. A simple on/off cycle will be illustrated using an idealized ocean GCM coupled to an energy balance model of the atmosphere. The on state produces clearly recognizable features of the modern ocean. The off state produces credible simulations of the d13C and CO3= distributions in the glacial ocean as inferred from benthic foraminifera. The basic on/off cycle also accounts for the correlation between atmospheric CO2 and Antarctic temperatures and the stable upper and lower limits in these quantities seen in successive glacial-interglacial cycles.

PP12C-06 1705h

The Tropical Respeonse to a North Atlantic Freshwater Forcing Experiment

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A growing body of evidence from paleoclimatic proxies suggests that tropical climate has varied on millennial to orbital timescales. Paleodata suggest that the tropics did undergo a climate change during the Younger Dryas ($\sim 12.7 - 13$ kyr BP), a cold event in the North Atlantic; however the nature of the tropical response is ambiguous. We present results of the tropical response to freshwater forcing experiments using the GFDL R30 coupled ocean-atmosphere general circulation model. Three freshwater forcing experiments were performed in which 0.1 Sv (1 Sv = $10^3 m^3 s^{-1}$) of freshwater was input into the North Atlantic for 100 years using modern day boundary conditions. Experiments such these are meant to simulate millennial-scale climate events, such as the Younger Dryas, which may have been caused by such freshwater inputs. Model sea surface temperatures warmed throughout much of the tropics in response to the freshwater forcing. This warming is greatest in the Atlantic (up to 0.6 °C), but reaches up to 0.2 °C in the Eastern Pacific. Subsurface warming (up to 0.5 °C) occurs throughout the water column in the Indian and Pacific Oceans as a result of a decrease in upwelling of the interior of the oceans. Preliminary data from the first experiment shows an El Niño-like response over the Pacific Ocean, with increased precipitation in the Western Pacific and a decrease in strength of the subtropical highs. The nature of the response agrees well with the model El Niño and with observed climatology. We test the robustness of this El Niño-like response using the two identical model runs also using the GFDL R30 coupled model. We present results from the three runs and discuss the nature of the response as well as reasons for discrepancies between the experiments.

PP21A MCC: Hall D Tuesday 0830h

Antarctic Climate Evolution I Posters

(joint with C, A, OS, GC)

Presiding: **R B Dunbar,** Stanford University**; M Siegert,** University of Bristol

PP21A-0298 0830h POSTER

Combining Glaciological Models and Tracers for Understanding Isotopic Records in Antarctica

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Understanding past climate over Antarctica and evaluating the isotopic composition of its large ice sheets remain challenges to elucidate for the paleoclimatologists' community. The present work combines glaciological models of various degrees of complexity to estimate these quantities from recently drilled ice cores (Vostok, Dome Concordia, Byrd...). A 1-D deposition model and a 2-D flow model are used in inverse mode to infer a range of possible temperatures and accumulation rates encapsulated within the ice cores. The inferred scenarios for the history of past climatic conditions are then prescribed to a 3-D forward model of ice sheet dynamics and thermodynamics (Ritz et al. 2001) coupled with a particle tracking model (Clarke et al., 2002) to simulate the evolution of the Antarctic Ice Sheets over four climatic cycles. The recently developped particle tracking model predicts the origin and the climatic conditions (at deposition) of all ice within an ice sheet: Date, surface temperature, accumulation rate, thinning of layers, chemical properties, spacial variability of origin: elevation and position. The model is used here for two specific purposes: Firstly, the model creates synthetic ice cores that can be compared to "real" cores, an excellent test for validating (a) the dynamics and thermodynamics of the ice sheet model, (b) the climatic scenario and (c) the hypotheses used for the inverse 1-D and 2-D models; secondly, the tracking model predicts the isotopic composition of the Antarctic Ice Sheets, a critical quantity for understanding marine sediment records.

PP21A-0299 0830h POSTER

Shallow Source Volcanic Aeromagnetic Anomalies over the WAIS Compared with Coincident Bedrock Topography

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Aeromagnetic and radar ice sounding results from the Central West Antarctica(CWA) aerogeophysical survey have enabled detailed examination of specific anomaly sources, previously interpreted as caused by late Cenozoic subglacial volcanic centers, compared to bedrock topography. A great deal of technical effort by the CASERTZ and SOAR operation was needed to produce magnetic data having the observed accuracies of a few nT. As a result, the data contoured at at 2 and 10 contour interval are proving quite valuable in resolving subtle features. Considering the approximately 1-km flight elevation over the snow surface and the 2-3-km ice thickness of the WAIS anomaly amplitudes are surprisingly high over most of the CWA area. In contrast is the essentially non-magnetic, interpreted nonvolcanic, terrane east of the CWA (Ellsworth crustal block)which was originally recognized in the 1960s from magnetic profiles, as geologically quite different. Using large scale, 2- and 10-nT-contour interval magnetic and 20-m bedrock elevation maps we compared a few hundred specific anomalies which all correlate with bedrock topographic expression, to quantify the relative abundance of interpreted volcanic anomalies having shallow magnetic sources. Of course, deeper magnetic structures in the bedrock are present but have longer wavelengths, lower gradients and mostly lower amplitudes than the highly magnetic late Cenozoic volcanic rocks. Although late Cenozoic volcanic activity may have had a significant influence on the behavior of the WAIS in the past, any Holocene influence is highly uncertain despite the presence of at least one active subglacial volcano (Blankenship et al., 1993) and sparse active volcanism throughout the area of the WAIS. Because the WAIS and the volcanic rocks are roughly of similar age it is critical that datable samples from subglacial volcanic centers be obtained when new ice drilling technology come on line in the near future (e.g. Clow et al., 2002).

Beneath the divide of the WAIS in the complex volcanic topography of the Sinuous Ridge there are 30 high amplitude (40-1200-nT), steep-gradient, shallow-source anomalies which can be correlated with bedrock topography. Most (21 of 30) of these sources correlate with slight to moderate (60-600 m) topographic expression at the base of the ice. We have interpreted previously (Behrendt et al, 1995;2002) that likely hyaloclastites and other volcanic debris (e.g. pillow breccia) were removed concomitantly with their injection into the moving ice as is the case in Iceland. Beneath the divide area of the WAIS some hyaloclastite(?) ridges have probably been preserved also as observed in Iceland.

There are eight examples of about 1 km or greater topographic relief on the bedrock. These anomaly sources at the base of the ice would rebound to elevations above sea level were the ice removed. We interpret these anomaly sources as evidence of subaerial eruption of volcanos whose topography was protected from erosion by competent volcanic flows similar to prominent volcanic peaks that are exposed above the surface of the WAIS. Further we infer these eight volcanoes as erupted volcanic edifices at a time when the WAIS was absent.

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PP21A-0300 0830h POSTER

The ANDRILL Initiative: Stratigraphic Drilling for Climatic and Tectonic History in Antarctica.

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Limited exposures of Cenozoic strata in Antarctica (due to ice cover) and the low number of stratigraphic drillholes on the continental margin has forced geoscientists to interpret ice sheet history from information derived from lower latitude proxy records. Leading paradigms have been driven by the oxygen isotope record from deep-sea cores and eustatic changes inferred from sequence stratigraphic records on passive continental margins. Interpretations based on these proxy records have little direct confirmation from geologic records in Antarctica. Sedimentary archives that were recently recovered by the Cape Roberts Project (CRP) prove that high-quality proximal records of past ice sheet behavior are obtainable. The ANDRILL (ANtarctic DRILLing) Initiative is a consortium of five nations Germany, Italy, New Zealand, United Kingdom and United States that proposes to drill a portfolio of sites in McMurdo Sound to recover new sections of Cenozoic strata from locations proximal to the ice sheet that are ideally suited to record and date ice sheet oscillations, and associated oceanic and climatic variations.

Five themes with an overarching climate and glacial focus are the core of ANDRILLs scientific plan and include: 1) glacial transitions/steps and stages in the development of the Antarctic cryosphere, 2) periods of climatic warmth, 3) orbital and sub-orbital climatic variability, and the role of Antarctic ice cover on global sea-level and oceanic circulation, 4) origins and adaptations of polar biota, and 5) Antarctic Rift evolution and uplift of the Transantarctic Mountains.

ANDRILLs McMurdo Sound Portfolio will achieve its scientific objectives through an integrated three-phase approach. The first phase comprises a geophysical survey program including gravity and magnetic surveys, and seismic acquisition from the sea-ice and ice shelf to document basin extent, architecture and to correlate drilling targets to existing drillcores. The second phase includes four seasons of drilling to obtain high-resolution, seismically-linked, chronologically well-constrained stratigraphic sections from the Antarctic margin to link proximal pre-glacial and interglacial-glacial records to proxy climate records from lower latitudes. The last phase will integrate newly acquired geological data into glaciological, climate and oceanographic models in order to determine global links and the past and future role of the Antarctic cryosphere in global environmental change.

New drilling tools are currently being developed from proven technology that was employed during the CRP. The new ANDRILL drilling systems will have the potential for: 1) high percentage core recovery (> 97%), 2) recovery of strata from a sea-ice and ice shelf platform over water up to 1000 m deep, 3) a drilling rate 2-3 times faster than the CRP system, and 4) recovery of soft sediment.

URL: http://andrill-server.unl.edu

PP21A-0301 0830h POSTER

Paleoenvironmental Change in the Holocene Sediments of Lake Maruwan Ooike on the Rundvagshetta, Soya Coast, Antarctica-The history of the Regression of the Ice Sheet and Uplift of Soya Coast-

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Holocene marine sediments including the marine molluscan fossils are distributed on the ice-free area of Soya Coast, Antarctica. These sediments are exposed around the freshwater Lake Maruwan Ooike on the Rundvagshetta area. Therefore, we can easily estimate the period of marine environment in the history of this lake. To clarify the paleoenvironmental change in Lake Maruwan Ooike, we carried out the coring used by 2m hand-pushing piston corer. We were able to get the good core. Coring site is located at the north part of lake, which the water depth is 9.8m. Core of 187cm is recovered at this site. The purpose of this study is to clarify the paleoenvironmental change of Lake Maruwan Ooike, and to discuss about the history of the regression of the ice sheet and uplift of Soya Coast. Sediment core (Mw-4 core) is divided to 4 sedimentary unit based on sediment facies. Unit I (0-60cm) consist of laminated silt with cyanobacteria and moss. Unit II (60-68cm) consist of laminated cyanobacterial deposits. In this unit, total organic carbon content (10-15%) is higher than other unit. Unit III (68-150cm) is massive diatomaceous mud including marine benthic foraminifer. Unit IV (150-187cm) is laminated diatomaceous mud. The 14C AMS dating performed using by the organic carbon in sediment at 6 horizon. Calculating from the sedimentation rate and the 14C AMS dating, the boundary age between Unit I and II is estimated with 2900 yr.B.P., and II and III is estimated with 3650 yr.B.P. Unit III and IV show marine environment from the occurrence of benthic foraminifera, *Trochammina antarctica* and so on. Unit II is estimated the salt lake condition from cyanobacterial flora and high total sulfur content. Unit I is the fresh water lake condition with cyanobacteria and moss flora. Inflow of melt water of ice sheet started from the upper part of unit II, and two-layer structure is formed to salt lake during this unit. The age of change from marine to fresh water environment is estimated about 2900 yr.B.P., then the relative sea level is 8m of recent altitude. This result is harmonious with the record of Holocene marine sediments on the ice-free area of Soya Coast.

PP21A-0302 0830h POSTER

Modelling Sediment Transport and Drifts

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Understanding the processes and phases of sediment transport and drift formation is essential for a reconstruction of their evolution. Our approach to evaluate the contribution of different processes to drift growth, especially the alongslope vs. downslope transport component, is numerical modelling.

For this work, we have selected the area of ODP Leg 178 on the western side of the Antarctic Penninsula, where a dense grid (4000 km) of seismic profiles and numerous cores document the presence of 8 sediment mounds along the continental slope. These mounds are interpreted to be drifts, though a contrasting model proposes a turbidity-current-dominated origin. We concentrate on Drift 7, which was covered by 1500 km of seismic reflection lines, four CTD sites and two ODP Leg 178 sites (1095 and 1096). Numerical modelling of the processes involved could favour one of the proposed models and answer the question regarding mound origin.

The forward modelling process needs a 3-D framework of seismostratigraphic and sedimentological input parameters to define the input data and boundary conditions of the numerical model. These include (a) boundaries of seismostratigraphic units or event horizons (e.g. events of erosion or non-deposition), (b) seismostratigraphic unit thicknesses, (c) granulometric changes i.e. grain-size distributions within seismostratigraphic units (d) physical properties of sediments at event horizons and, (e) lithological changes.

In general, we aim at the inversion of an observed sediment structure into the depositional process. I.e. from the observation we want to deduce information on the generating current. This information comprises of current (steady and tidal) velocity and direction, the epoch when the current was active and its duration. This will lead to a better understanding of the processes responsible for sediment transport and erosions by oceanic currents. The problems we want to solve can be summarised as follows:

1. Is an initial topography (large-scale or mesoscale topography or inhomogeneity in sediment distribution) necessary for the formation of a structure like a sediment drift?
2. What current velocities are needed to a) transport and b) deposit sediment?
3. Does the current velocity need to be maintained for the whole period or is the shaping of the sediment drift favoured by episodic changes in current velocity?
4. How long would an episode of current activity have to be in order to generate the morphology observed in a sediment drift?

Preliminary work on the high-resolution seismic reflection data and granulometric work within the seismostratigraphic units has shown clear variability in the grain size that could be correlated, if only tentatively at this time, to know changes in the development of the Antarctic ice sheet in response to climatic change. Further analysis and correlation between the geological and geophysical data form work in progress.

PP21A-0303 0830h INVITED POSTER

The ACE (Antarctic Climate Evolution) Research Initiative

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ACE (Antarctic Climate Evolution) is a new international research initiative to study Antarctic climate and glacial history, by linking climate and ice sheet modeling studies with geophysical surveys and geological studies on and around the Antarctic continent. The Antarctic ice sheet has existed for approximately 35 million years, but it has fluctuated considerably throughout the Cenozoic. The spatial scale and temporal pattern of these fluctuations has, however, been the subject of considerable debate. Determining the scale and rapidity of the response of the cryosphere to climatic forcing is important, because ice-volume variations lead to changing global sea levels on a scale of tens of meters or more. Numerical climate and ice sheet models have been developed to simulate the behavior of the Antarctic ice sheets. Some of these models have been successfully validated against modern conditions. Modeling the past record of ice-sheet behavior in response to climatic forcing is the next step. The ACE program aims to facilitate research in the area of Antarctic climate evolution by linking geophysical surveys and geological studies on and around the Antarctic continent with climate, ocean, and ice-sheet modeling studies. These studies will investigate the evolution and behavior of Antarctic climate and ice sheets over a wide range of time scales throughout the Cenozoic, including times when global temperatures were several degrees warmer than today. The ACE program will 1) encourage and facilitate communication and collaboration between research scientists working on different aspects of Antarctic climate, oceans, and ice sheets; 2) provide assistance on technical issues related to field and laboratory programs and to ice-sheet and paleoclimate modeling studies; 3) promote data access and facilitate data syntheses; and 4) report the results of these efforts to the scientific and wider community on an ongoing basis at workshops, symposia, and in the primary literature. ACE is not yet an official program. The Scientific Committee on Antarctic Research (SCAR) has now set up a Scientific Programme Planning Group to develop a

programme for ACE to operate as a sanctioned, international research initiative, operating under the SCAR umbrella. Additional information on ACE can be found at http://www.geo.umass.edu/ace.

PP21A-0304 0830h POSTER

Trough-mouth-fan Evolution on the Pacific-Margin of the Antarctic Peninsula Outer Continental Shelf and its Relation to Sediment Drifts on the Adjacent Continental Rise

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Rebesco et al. (1998) propose a general depositional model that relates sediment drift evolution on the Antarctic Peninsula Pacific-margin abyssal plain to glacial processes on the continental shelf. In their model, the terrigenous sediment were directly delivered to the rise and contributed to the construction of large sediment drifts when grounded ice sheets extended to the shelf edge. In this scenario, large volumes of sediment by-passed the margin at the mouth of ice streams (i.e., fast flowing ice), whereas prograding slopes were constructed on those portions of the shelf margin between major ice streams. This model relies heavily on the modern geomorphology of the margin. In contrast, an evaluation of the subsurface stratigraphy suggested that there may have been significant lateral shifts of ice-stream locations and associated trough-mouth-fan depositional systems through time (Bart and Anderson, 1995). New seismic data acquired along the strike of the Antarctic Peninsula shelf during the 2002 season aboard the NBP R/VIB confirm that slope progradation between the modern troughs was indeed associated with large ice streams. Moreover, the data illustrate that the last several glacial cycles did not produce significant slope progradation anywhere along the margin which signifies a major change in the stratal-stacking pattern on the outer continental shelf. This change in stacking pattern is roughly coincident with a major reduction in sedimentation rates on at least two of the drifts (i.e., those drilled at ODP Sites 1095 and 1101).

PP21A-0305 0830h POSTER

Sediment Texture as a Recorder of Past Sea Level Changes - Examples from the Pliocene of New Zealand and the Oligocene of Antarctica

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Variations in sediment texture off prograding wave-graded coasts often follow the same pattern - a progressive change from well-sorted sand on the beach face to moderately-sorted muddy sand around fairweather wave base and finally to poorly-sorted mud beyond storm wave base. We attribute this offshore fining pattern to a decrease in wave-induced bed shear stress with increasing water depth, whereby sand introduced to the coast by rivers is transported primarily across the bed and accumulates nearshore whilst mud remains in suspension nearshore but settles out offshore. The resulting systematic increase in percent mud offshore comes from the mixing of these two populations and relates directly to water depth for a particular wave climate. Because bed shear stress can be estimated from wave statistics it should be possible to predict the depth at which mud will begin to accumulate on open coasts. Furthermore, where the paleogeography of inner shelf sedimentary sequences is known, percent mud becomes a reasonable proxy for estimating paleo water depth.

We collected samples from a shore-normal transect off the coast of Manawatu, New Zealand (moderate waves, H = 0.5 m, T = 7 s) and used the percent mud as a basis for estimating past water depth from Pliocene cyclic inner-shelf sediments from the nearby Rangitikei Basin. We also estimated past water depth for Oligocene cycles cored by the Cape Roberts Project off the Victoria Land coast of Antarctica (when the coast was largely ice-free). In both cases we have made detailed measurements through several lithological cycles, each thought to represent relative sea level change due to obliquity (41 ky period) forcing.

The Rangitikei cycles, which are tens of m thick, range from muddy sand through fine mud and back to sand. The CRP cycles are similar in scale, recording relative sea level changes of the order of tens of metres but most cycles begin with a glacial diamict resting on an erosion surface, representing retreat of the ice and the start of a new cycle. Using the Manawatu coast as an analogue, we suggest the sandy sediments were deposited in water depths of less than 20 m, whilst sediments with more than 85 % mud were deposited at depths greater than 50 m. Thus the total relative sea level change in each cycle, as recorded by sediment texture, is at least 30 m.

URL: http://geo.vuw.ac.nz/croberts

PP21B MCC: Hall D Tuesday 0830h

Middle to High-Latitude Paleoceanography and Paleoclimatology Posters *(joint with A, OS, GC)*

Presiding: **E Levac,** St. Francis Xavier University**; P deMenocal,** Lamont-Doherty Earth Observatory of Columbia University

PP21B-0306 0830h POSTER

Differences Between Labrador Sea and North Atlantic Heinrich Layers:Implications for Iceberg Supply and Meltwater Discharge

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Further study of fifty cores from the Labrador Sea reveals the presence of eight Heinrich events, i.e., H0-H6, including H5a. Heinrich layers in the Labrador Sea are identified by their high detrital carbonate concentration, increased coarse-fraction content, and lighter 18O values in Neogloboquadrina pachyderma (sinistral). Heinrich layers in ice-proximal regions of the Labrador Sea are dominated by nepheloid-flow deposits that are recognized in X-radiographs as thin graded mud layers with floating coarser grains of ice-rafted detritus (IRD) as opposed to those in the North Atlantic which consist of pelagic sediments rich in IRD. The concentration of IRD within Heinrich layers H1 and H2 in the upper slope of the northwestern Labrador Sea cores shows a double peak dominated by detrital carbonate grains, whereas the lower-slope and deep Labrador-basin cores show a single peak. These findings are in contrast with North Atlantic Heinrich layers that are characterized by a double peak of IRD; a peak of quartz and volcanic grains followed by a carbonate peak. There are light dO18 peaks observed immediately prior to H2 and H1 which are neither associated with an increase in IRD nor with the concentration of detrital carbonate. The distribution and thickness of Heinrich layers suggest that iceberg discharge during different Heinrich events in the Labrador Sea followed different drift routes. Heinrich-like event H0 is present only in the upper slope cores of the northwestern Labrador Sea close to Hudson Strait but absent in the lower slope and deep-basin cores. During or prior to H0, the Laurentide Ice Sheet may have retreated to the inner shelf (or more landward), hence the glaciomarine sediments delivered to the inner shelf and icebergs were transported by the already established Labrador Current. On the other hand, during the deposition of earlier Heinrich events, iceberg discharge was so massive that it overwhelmed the Labrador Current and swamped the open Labrador Sea with icebergs. A narrow light dO18-Npl peak at the end of H2 and H4 preceded by heavier values during these events in all proximal cores suggests that the iceberg supply was predominant over meltwater discharge. This might indicate that ocean surface temperatures were too low to allow major iceberg melting toward the end of those Heinrich events when warming started. It is proposed that H3 and H5a in the Labrador Sea, on the other hand, may have been associated with major melt-water discharge.

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Sub Millennial-Scale Climate Variability off the Western Iberian Margin During the Penultimate Glacial Period (MIS 6)

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High-resolution palaeoclimate records of planktonic foraminiferal fauna, stable isotopes and ice-rafted debris counts obtained from the Portuguese margin (40°N, 9°W) exhibit large fluctuations during the penultimate glacial period (MIS 6). This study focuses on four main points: 1) the distinction between cooling episodes related to Heinrich-type ice-rafting events and those related to increased regional upwelling, 2) the magnitude and apparent similarity in the frequency of climate change associated with ice-rafting events to those described during the last glaciation, 3) the effect on the ventilation of North Atlantic Deep water during the most important cold events, and 4) the variability of the Portuguese benthic *delta* ^{18}O and the Vostok methane record seemingly in phase.

Sea-surface temperature off Portugal in Stage 6 was in general warmer than during the last glacial, pointing towards a weaker southward influence of polar water masses. Ice-rafting occurred mainly in mid-MIS 6 (between 163 and 143 kyrs) as a group of poorly differentiated, short duration quasi-continuous events, mainly marked by the high abundance of sinistral *N. pachyderma*. Differences exist in IRD composition relative to the last glacial, with a reduced Canadian-derived detrital carbonate component, combined with an important contribution of volcanic particles originating from northern Britain and Icelandic ice-sheets. The lower magnitude and higher frequency of these events suggests that the warmer temperatures would have induced iceberg waning closer to the source areas.

Centennial periodicity similar to that observed in Stage 3 (700 years) is also a persistent feature of the penultimate glacial, although the group of mechanisms behind this variation is not fully understood. Solar radiation changes may exert some control, and it is reasonable to surmise that a diverse combination of forcing factors and reaction times of the different components of the complex ocean-atmosphere-ice-sheet system would have produced a record with the same cyclicity in the deep-sea sediments.

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Pleistocene Changes in Sea of Okhotsk Hydrography and Productivity

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The Sea of Okhotsk (SOk), a marginal sea of the North Pacific, is characterized by a unique climatic situation that leads to a specific hydrography and productivity regime that makes this ocean area to one of the most productive areas of the world ocean. Because the specific environmental conditions are strongly influenced by the Siberian climate at one side and the global oceanic circulation on the other, the SOk represents a key area to investigate the interaction of land and ocean governed climate processes. The other important hydrographic feature of the SOk is the Sea of Okhotsk Intermediate Water, which is considered to be an important source for the North Pacific Intermediate Water and therefore to play a key role in ventilating the North Pacific. Thus the reconstruction of the paleoceanographic conditions in the SOk might give further