PP12B-06 1445h

Possible Isotopic Evidences of Post Marinoan of Neoproterozoic III in Three Gorges Area, China

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Well world widely correlated Neoproterozoic III, upward includes Doushantuo Formation and Dengying Formation, overlays tillite of Nantou Formation and Gucheng Formation in Three Gorges area, China. The section has well controlled on biostratigraphy and sedimentology, such as complex of small shelly fossils yield around Precambrian-Cambrian boundary at the top of the section, Vendotaenids yield in the lower part of Dengying Formation, acritarches in Doushantuo Formation, and cap dolomite at the base of Doushantuo Formation which overlay tillite unit of Nantou Formation at the base of the section. Strontium, carbon oxygen isotope presents significant excursions in this well-developed carbonate section that is located at Wuhe near Zhigui in the area. 1) Carbon isotope (δ_{13}C) dramatic dropped from $4^o/_{oo}$ to $C8^o/_{oo}$ (PDB in this paper) near the boundary of Doushantuo and Dengying Formation, and elevates around $4^o/_{oo}$ at lower part of Dengying Formation where oxygen isotope (δ_{18}O) raises to $0.5^o/_{oo}$ from $C7^o/_{oo}$ at the upper part of Doushantuo Formation. Strontium isotopic ratio ($^{87}Sr/^{86}Sr$ in this paper) is discovered a peak as high as 0.7100 in the base of Dengying Formation, and exhibits important excursions across the boundary from 0.7077 on the upper part of Doushantuo Formation and 0.7084 on the lower part of Dengying Formation. 2) A world widely typical excursion of carbon and strontium isotopes are confirmed span the boundary of Precambrian-Cambrian where controlled by a complex of small shelly fossils at the top of the section. 3) Abnormally isotopic excursions around the boundary of Doushantuo and Dengying Formation may be the possible evidence of post Marinoan ice age.

PP12C MCC: 270 Monday 1530h

Interhemispheric Climate Change II

(joint with A, OS, GC)

Presiding: **J R Toggweiler,** NOAA Geophysical Fluid Dynamics Laboratory**; P U Clark,** Oregon State University

PP12C-01 1530h INVITED

Coupling of the hemispheres in observations and simulations of glacial climate change

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We combine reconstructions, climate model simulations and a conceptual model of glacial climate change on millennial time scales to examine the relation between the high latitudes of both hemispheres. A lead-lag analysis of synchronised proxy records indicates that temperature changes in Greenland preceded changes of the opposite sign in Antarctica by 400-500 years. A composite record of the Dansgaard-Oeschger events shows that rapid warming (cooling) in Greenland was followed by a slow cooling (warming) phase in Antarctica. The amplitudes, rates of change and time lag of the interhemispheric temperature changes found in the reconstructions are in excellent agreement with climate model simulations in which the formation of North Atlantic Deep Water is perturbed. The simulated time lag between high northern and southern latitudes is mainly determined by the slow meridional propagation of the signal in the Southern Ocean. Our climate model simulations also show that increased deep water formation in the North Atlantic leads to a reduction of the Antarctic Circumpolar Current through diminishing meridional density gradients in the Southern Ocean.

We construct a simple conceptual model of interhemispheric Dansgaard-Oeschger oscillations. This model explains major features of the recorded temperature changes in Antarctica as well as the general shape of the north-south phase relation found in the observations including a broad peak of positive correlations for a lead of Antarctica over Greenland by 1000-2000 years. The existence of this peak is due to the regularity of the oscillations and does not imply a southern hemisphere trigger mechanism, contrary to previous suggestions. Our findings thus further emphasise the role of the thermohaline circulation in millennial scale climate variability.

PP12C-02 1550h INVITED

Chronology of Millennial-Scale Climate Change at Siple Dome, West Antarctica

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Ice core paleoclimate records from both hemispheres can be placed on common chronologies using records of long-lived atmospheric gasses. We used records of methane from 11-45 ka and δ^{18}O of O_2 from 11-90 ka to place the Siple Dome stable isotope record on a common time scale with GISP2. This record allows us to compare the relative timing of millennial-scale events in Greenland and Antarctica and specifically to test the "see-saw" pattern of Greenland/Antarctic warming and cooling inferred primarily from the Byrd and GISP2/GRIP ice cores. The precision of the comparison varies, but is as good as 0.3-0.4 ka at times of rapid change in atmospheric methane. During the last deglaciation, the main warming at Siple Dome preceded the onset of the Blling period in Greenland by approx. 5 ka. A plateau in the warming trend from approx. 15-13 ka appears to be the expression of the Antarctic Cold reversal (ACR) at Siple Dome and ends at the onset of the Younger Dryas in GISP2. This plateau starts at approx. 15.3 ka in our chronology. Its onset is either synchronous with, or slightly leads, the onset of the Blling period in Greenland, although interpretation is complicated by evidence for a depositional hiatus at Siple Dome. During MIS-3 the gradual warming associated with Antarctic events A1 and A2 at Siple Dome preceded, by approx. 1.3-1.5 ka, the rapid onset of warming at D-O events 8 (38.5 ka) and 12 (45.5 ka) at GISP2. The cooling phase of these Antarctic events started at about the time that Greenland warmed. Smaller Antarctic warmings following A1 apparently preceded D-O events 7, 6, and 5 by approx. 0.6-1.0 ka. The chronology of millennial-scale events in the older section of the Siple Dome record (45-90 ka) is currently less precise but strongly suggests that Antarctic events A3 and A4 preceded D-O events 14 (52.3 ka) and 16/17 (58.5 ka) by 3.5 and 2.4 ka, respectively. This suggestion will be tested with higher resolution comparison offered by the methane record for this section of Siple Dome (now in progress). The pattern and timing of millennial warming and cooling in the Siple Dome record are very similar to that at Byrd. This similarity strengthens the argument for dynamically important interhemispheric differences in timing of millennial-scale climate change, although new ice core records with adequate chronology are necessary to understand the spatial pattern of this phenomenon in Antarctica.

PP12C-03 1610h INVITED

Deuterium excess at Siple Dome, West Antarctica: A role for the Pacific in millennial-scale climate change?

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Deuterium excess is a parameter measured in ice cores that tracks changes in the conditions of the ocean surface during evaporation, primarily sea surface temperature and to a lesser extent, wind speed and humidity. Based on simple and complex atmospheric models, as well the presence of strong ENSO signals, Siple Dome in West Antarctica appears to get its moisture predominantly from the sub tropical Pacific, in contrast to ice cores from East Antarctica which are fed primarily with moisture from the Atlantic and Indian oceans. The Siple Dome ice core, therefore, is one of the first ice cores to contain a record of the Pacific Ocean surface conditions over the past 100,000 years. The Siple Dome ice record of climate has been placed on a common time scale with GISP2 using records of long-lived atmospheric gasses, methane and d18O of O2 (see Brook and others, this session). The delta D record from Siple Dome appears to reinforce the observation that millennial scale climate changes are not in phase between Antarctica and Greenland (including the presence of an Antarctic Cold Reversal in Siple Dome), and confirms the robust observation that the magnitude of millennial scale climate changes in Antarctica are very small compared to those seen in Greenland. Scaled to the glacial-interglacial delta D change, D-O events in Greenland are 5 to 10 times larger than the stage 3 oscillations in Antarctica. In contrast, deuterium excess changes in Siple Dome are very large. Using the same scaling, XS changes in Siple Dome are comparable in magnitude to the delta D changes seen in Greenland. In addition, the XS changes are out of phase with delta D at Siple Dome, and thus appear to be in phase in Greenland delta D. XS peaks in the Siple Dome ice core, suggesting warmer Pacific SSTs, correspond with nearly all of the D-O events, raising the potential for a role for the sub-tropical Southern Pacific Ocean in millennial scale climate change, with phasing coherent with the Greenland records. In addition, during the transition and into the Holocene, XS continues the strong 1,500 and 3,000 year oscillations it has during the older parts of the record. Notably, there are relatively large increases in XS at 11.9 kybp (near the end of the Younger Dryas) and at 14.7 kybp (near the beginning of the Bolling-Allerod warming).

PP12C-04 1630h

Gulf Stream Variability, Ice-Rafting Events and Greenland Record Between 24 and 64 kyrs

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We present detailed results obtained from ODP Leg 172 Site 1060, from the Black Bahamas Outer Ridge at 74°W, 31°N, 3500 meters water depth. This site is at present under the influence of the Gulf Stream and the North Atlantic Deep Water.

At this location the foraminiferal faunas demonstrate a clear millenial-scale variability during MIS3. Faunas are dominated by warm species during interstadials, typically 60% associated with the warm water of the Gulf Stream, while this group only makes up about 30% of the fauna during stadials. An age model has been constructed by correlating abrupt shifts in the relative abundance of this faunal group with abrupt changes in the isotopic composition of ice in Greenland (time scale of Johnsen et al. 2001).

On this time scale, the benthic oxygen isotope record for MIS3 at Site 1060 is similar to that generated

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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