Heinrich-like Events in the Southeast Pacific:
Abrupt Climate Change During the Last Interglacial

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1. Introduction

Recurring intervals of rapid climate change inferred from layers of high lithic content and low foraminiferal abundance have been observed in North Atlantic. These horizons are known as Heinrich events and are interpreted to represent episodes of glacial calving and ice melting[1].

Previous studies have addressed Heinrich events primarily in the Northern Hemisphere but proposed forcing mechanisms[2] suggest that evidence of ice rafting should be observable globally in sites proximal to ice margins.

This study focused on Marine Isotope Stage 5 (MIS 5) (Fig. 1), as observed in a sediment core from the Chilean Margin. Our sample site is ideally situated to record episodes of ice rafting from Patagonian glaciers.

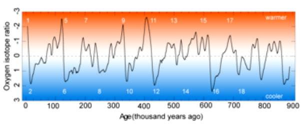
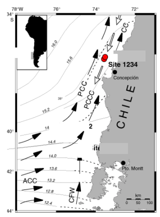


Figure 1. Oxygen isotope ratios ($^{18}O/^{16}O$) preserved in foraminifera record a history of earth's temperature and ice volume and consequently glacial and interglacial phases. These phases are paced by changes in solar insolation (Milankovitch Forcing)[3].

2. Core Information

- Site 1234 was cored in 2002 during ODP Leg 202 (Fig. 2)[4]
- Core taken from hemipelagic sediments in 1015 m water located 65 km off the coast
- Core sedimentation rate of ~79 cm/kyr
- Chronostratigraphy established through correlation with the Vostok ice core chronology of Shackleton *et al.*, 2004



- 45 samples selected from ~ every 1,300 yrs
- Freeze dried, weighed and washed using 63 µm sieves, then dried and re-weighed
- Passed through 150 µm sieves to separate fine-grained material (potential eolian inputs)

Figure 2. Locations of Site 1234 and oceanographic features on the Chilean Margin (ACC = Antarctic Circumpolar Current, PCC = Peru-Chile Current, PCCC = Peru-Chile Countercurrent, CC = Chile Coastal Current, CFW = Chilean Fjord Water). Modern mean annual sea-surface temperatures[4].

3. Foraminifera

- Samples were counted to determine foraminiferal abundance with particular attention to *Neogloboquadrina pachyderma* sinistral
- Individual foram species (Fig. 3) were picked and sent for oxygen isotope analysis to the Wright Stable Isotope Lab at Rutgers University

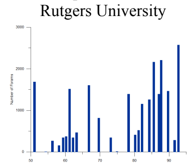


Figure 4. Histogram of total number of foraminifera in each sample.

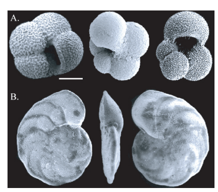


Figure 3. Scanning electron microscope images of A. planktic foraminifera, from left to right: *N. pachyderma* s., *N. pachyderma* d., *G. bulloides* and B. benthic foraminifera *Cibcidoides sp.*. Scale bar is 0.1 mm[5].

4. Ice Rafted Detritus

- Grains greater than 150 µm were selected
- Samples were split so that each contained approximately 400 grains
- Grains were identified and divided into groups (Fig. 5)
  - A. Minerals
  - B. Volcanic glass
  - C. Volcanic rock fragments

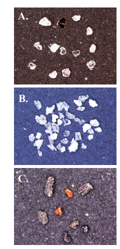


Figure 5.

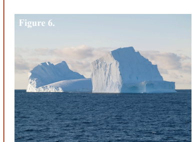


Figure 6.

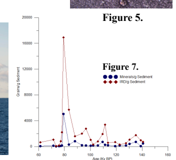


Figure 7.

Figure 5. Stereomicroscope images of **A.** minerals, **B.** volcanic glass, **C.** volcanic rock. Size range: 150 - 300 µm.

Figure 6. Iceberg carrying ice rafted detritus[6].

Figure 7. Component plot of mineral contributions to total ice rafted detritus exhibiting a steady correlation between high mineral abundance and a high abundance of ice rafted detritus. The strong correlation suggests that eolian inputs are minimal, except at 80 kyr.

5. Results

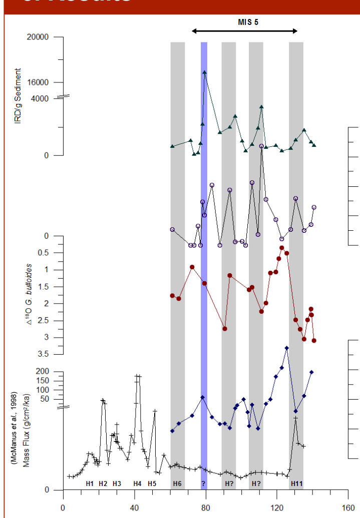
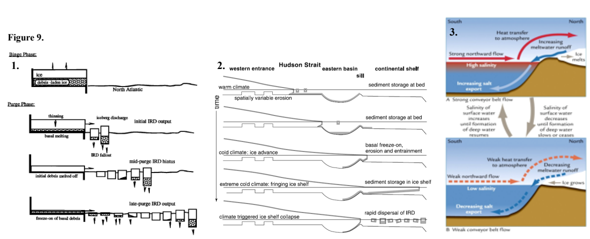


Figure 8. Plots of IRD/g Sediment, % *N. pachyderma (s.)*, $\delta^{18}O$ of *G. Bulloides*, $\delta^{18}O$ of *Cibicidoides sp.* and Mass Flux ($g/cm^2/ka$)[7] all versus age. Our data clearly resolve MIS 5 and show it to be in phase with Greenland warming. Increases in IRD/g Sediment, abundances of *N. pachyderma (s.)* and heavier isotope ratios (cooler temperatures) in planktonic and benthic foraminifera are tied to Heinrich events in the North Atlantic as recorded in Mass Flux data (grey lines). An additional event is suggested (blue line) at ~ 79 kyr. Events between H11 and H6 had been previously predicted[1] but not found in all North Atlantic cores.

Figure 9. Three mechanisms have been proposed to explain the forcing of Heinrich events. **1)** The Binge/Purge model[8] **2)** Rise and Collapse[2,9] and **3)** the Salt Oscillator[10,11]. The Binge/Purge model cannot have driven ice rafting events in the South Pacific because continental ice sheets do not exist in the Andes. The Salt Oscillator model would predict antiphased events in the Northern and Southern Hemispheres which is inconsistent with our observations. The Rise and Collapse hypothesis might serve to explain global ice rafting events.

Figure 9.



6. Conclusions

1. **MIS 5 is clearly recorded in the marine sediments of the Chilean Margin and is in phase with Greenland warming**
2. **Heinrich-like events are a feature of the Southeast Pacific**
3. **We have identified two ice rafting events with possible North Atlantic analogues**
4. **Southern Hemisphere Heinrich-like events are in phase with those in the North Atlantic suggesting that the Binge/Purge and Salt Oscillator models are insufficient to explain the forcing of Heinrich events**
5. **The sea level 'Rise and Collapse' hypothesis might serve to more completely explain global ice rafting events**

7. References

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6. Photo by Patrick Rowe for the National Science Foundation.
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