# The Paleoventilation of the South Pacific

**Sarah Hope Edwards[1], Elizabeth Sikes[2], Thomas Guilderson[3]**

[1]University of Wisconsin-Madison, Madison WI, [2]Rutgers University, Institute of Marine and Coastal Sciences, New Brunswick, NJ, [3]Lawrence Livermore National Laboratory, Center for Accelerator Mass Spectrometry, Livermore, CA

## Introduction

Deep water currents in the modern ocean are formed in the North Atlantic, flow south and then to the east around the southern tip of Africa. This colder, denser and more saline water fills the water column below the thermocline as it flows through the Indian Ocean, and enters the Pacific moving north to the east of New Zealand. In the Southern Ocean this deep water flow outcrops because of the absence of a permanent thermocline and partially re-equilibrates with the atmosphere before sinking again to continue its global deep water circulation route.

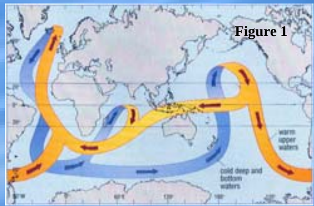



Figure 1

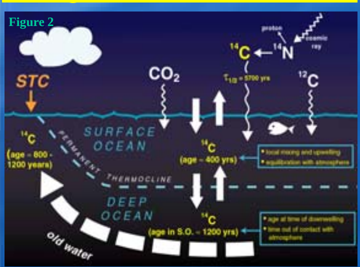
The route of the global deep water circulation (Figure 1, above) is dictated by the waters' physical attributes and ocean floor morphology. In the deep Pacific waters move north at deepest depths and return at mid depths

During the last glaciation ice coverage in the polar regions changed the formation of deep waters in the North Atlantic, slowing down and modifying the properties of those deep waters. It is has also been speculated that the speed and depth of deep flow and the return mid depth flow may have changed.

The ocean holds magnitudes more of the greenhouse gas $CO_2$ than the atmosphere, ocean circulation and deep water residence time both have a strong influence on carbon cycling and thus on climate. Global ventilation rates during the Last Glacial Maximum have not been well quantified, the past residence time of $CO_2$ in the world's oceans is uncertain. Constraining the past ages of surface and deep waters helps quantify past changes in ocean circulation. Acquiring and interpreting data from critical locations such as the South Pacific improves reconstructions of past ocean circulation and climate fluctuations.

## $^{14}C$ Ages in the Modern Ocean

Figure 2




Ocean water has radiocarbon ages, with modern surface waters dating to ~400 years and deeper waters dating in the ~700 to 1500 year range, as shown in Figure 2 (left). The deep water is "older" as it does does mix through the thermocline; surface waters do not date to zero years due to the time it takes for atmospheric $CO_2$ to enter the ocean as well as due to some mixing with deeper, older waters. These age dates are used as a tracer of ocean circulation, and are especially useful in vertical profile. The cosmogenic deposition of $^{14}C$ is assumed constant during the last glaciation.

## Sample Locations

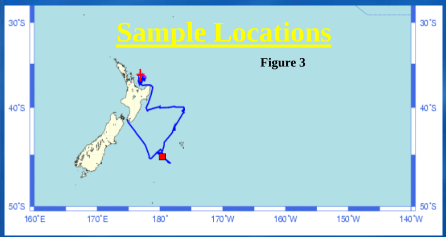



Figure 3: Sample locations in the South Pacific. The samples used for this study were taken from the Bay of Plenty (red cross) and south of the Chatham Rise (red square) to obtain different depths in the water column of the same tephra.

## Correlation of Kawakawa Tephra with Terrestrial Deposit

Figure 4 (right): The correlation of Kawakawa ash layer (or tephra) between terrestrial and marine deposits is done by chemical fingerprinting. The Kawakawa dates to 22,590 $^{14}C$ years BP on land. Ash layers provide a stratigraphic tie with terrestrial deposits. Sampling at the ash layer limits errors introduced by bioturbation. For each core and depth radiocarbon dates both above and below the Kawakawa ash layer were obtained. The Bay of Plenty and Chatham Rise are ideal locations for such a study, as several of the Quaternary New Zealand ashes have widespread deposition in these areas. Chemical identification of ash for this study was done by Dr. Phil Shane (Auckland University, New Zealand).

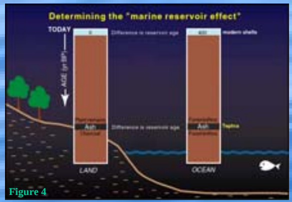
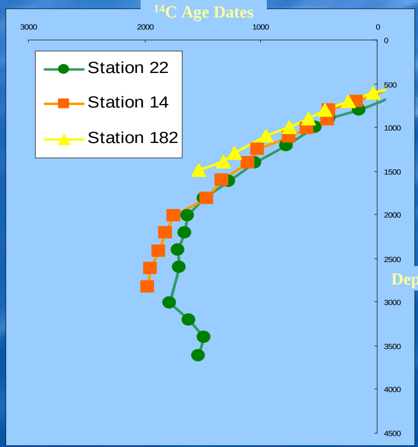



Figure 4

## WOCE Station Data

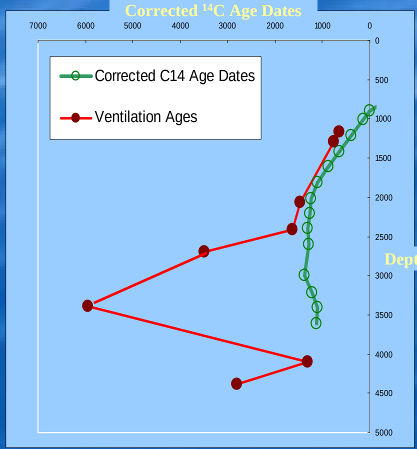
| Station | Latitude | Longitude |
|---|---|---|
| 14 | 42.995° S | 150.50° W |
| 22 | 47.003° S | 150.4.88° W |
| 182 | 32.500° S | 179.918° E |




**Graph 1 (above): WOCE (World Ocean Circulation Experiment) data from three stations in the South Pacific. Station 22 is deep enough to show the modern circulation pattern of oldest waters at mid depth, but is from well south of the study area. Station 182 and 14 confirm similar $^{14}C$ profiles from nearer to the sample locations.**

## Glacial Ventilation Ages

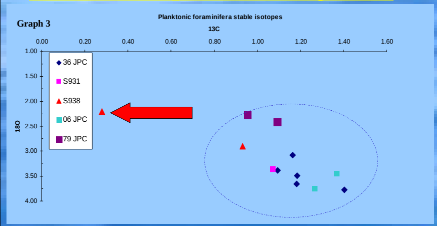
| Location | Core | Depth | Calculated Surface to Deep Age Difference |
|---|---|---|---|
| Bay of Plenty | 79JPC | 1165 | 632.5 |
| South Chatham Rise | 06JPC | 3385 | 5940 |
| Hikurangi | 36JPC | 4389 | 2810 |




**Graph 2 (above): Modern $^{14}C$ ages (WOCE Station 22) and compiled sedimentary glacial data. New data generated in this study is tabulated above. Oldest waters are deeper than present, at 3000-3500m (lower mid depths). Deepest waters were younger than mid-depths in the last glaciation. Oldest waters were 2 to 5 times older than today.**

**The glacial data is generated on foraminifera from above and below the tephra. Values are averaged together, then the planktonic ages are subtracted from benthic ages. By doing this, surface reservoir values are erased. In order to compare the WOCE data in this plot to sedimentary values, it has been "corrected" by subtracting 400; also removing the surface reservoir value.**

## Stable Isotope Confining Data




Graph 3 (above): Stable isotopes, $\delta^{18}O$ and $\delta^{13}C$ of the planktonic foraminifera (*G. inflata*). Stable isotopes reflect ocean circulation and glacial values are well quantified globally. We can use stable isotopes to confirm that most of the samples were in fact from the last glacial maximum and not reworked or otherwise contaminated. Sample S938 (red triangle to left with red arrow), however, does not lie in the glacial zone as it does not have $^{18}O$ values of ~3-4. This previously obtained but not published value has been left out of the radiocarbon graphs (to the left) as those numbers would also be inaccurate. A similar plot was also done for the benthic samples on the genus *Cibicidoides*.

## Why Foraminifera?

Foraminifera are a diverse group of protists with calcium carbonate (the mineral calcite) skeletons. As they grow, they are in equilibrium with their marine environment; and after they die, their skeletons sink to the seafloor, recording that environment. They are ubiquitous in the marine geologic record and are commonly used in biostratigraphy; like most plankton, speciation and extinction is recorded worldwide. Different species, however, are more common in different environments, or may vary in habitat which affect how well they record deep water signals. Complications using foraminifera arise with these variations, as well as from some species of benthic foraminifera that agglutinate calcite rather than precipitate it themselves.

## Conclusions

1. **Surface to deep ages were larger during the Last Glacial Maximum than present, indicating less ventilation of deep waters in the past.**
2. **In the southern Pacific, the oldest ages were at lower mid-depths. Therefore, the overall circulation had the same pattern as the modern ocean, with a mid-depth older current.**
3. **Stable isotope data can confirm the validity of the radiocarbon data.**

## Sample Preparation

Image 1.

Core split on ship, sampled.

Image 2.

Mud washing (to sieve clay and ash particles from sand-sized foraminifera).

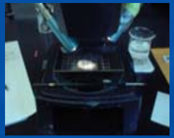


Image 3.

Foram picking done by hand in lab at Rutgers.

## Examples of Planktonic Foraminifera

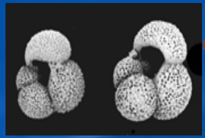
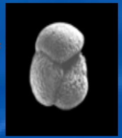


Image 4 (left).

Example of *G. bulloides*

Image 5 (right).

Example of *G. inflata*



**About 700 milligrams of calcite for each species from each sample is needed to obtain $^{14}C$ dates. The size of the foraminifera picked is in the 100-250 micron range. Several hundred specimens of each of the two planktonic species is required for radiocarbon dates, while stable isotopes require a few *Cibicidoides* and 10+ *G. inflata*.**

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