STABLE ISOTOPIC AND TRACE METAL ANALYSES OF TWO *PORITES LOBATA* COLONIES – OAHU, HAWAII: IMPLICATIONS FOR PAST SEASONAL VARIATION AND SEA SURFACE TEMPERATURES AND ANTHROPOGENIC EFFECTS ON THE REEF ENVIRONMENT.

Abstract of

a thesis presented to the Faculty

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Abstract

Corals from the western and equatorial Pacific Ocean have been extensively studied for the purposes of generating paleoclimate reconstructions spanning the last several hundred years. However, in the central subtropical North Pacific, there are currently few published coral records extending beyond 10 to 20 years. The hermatypic coral species *Porites lobata* and *Porites lutea* have proven to be useful indicators of paleoclimate and past sea surface conditions at other locations. Here I have analyzed two *Porites lobata* coral cores collected from colonies from opposite sides of Oahu, Hawaii to assess their utility for developing multi-decadal length climatic reconstructions in this region.

The two coral records are from Punalu'u Beach (157.881607°W, 21.576752°N) and Waikiki Beach (157.881607° W, 21.576752° N) and presented here are isotopic ($\delta^{18}O$ and $\delta^{13}C$) and trace metal data (Sr/Ca, Pb, and other metals) from these two corals. An absolute increase in sea surface temperatures of 1°C over the last 40 years is clear in the instrumental SST data, along with a clear bias towards the times of maximum SST during a negative phase of the Pacific Decadal Oscillation (PDO). Lead (Pb) concentration for one of the corals also coincides with the change in the PDO seen in 1976, with Pb concentrations decreasing from ~4-6ppm to between 0.5-1ppm. However, I infer this decline in concentration is more probably due to the elimination of lead in gasoline. Other trace metal data trends show increased concentrations of specific metals during times of known Kona storm events. Presented here is the longest sub-annual resolution paleoclimate record derived from Hawaiian corals along with a comprehensive analysis of their usefulness as a paleoclimate and environmental change indicator.

University at Albany, State University of New York

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Jonathan MacDonald

under the title

Stable isotopic and trace metal analyses of two *Porites lobata* colonies – Oahu, Hawaii: Implications for past seasonal variation and sea surface temperatures and anthropogenic effects on the reef environment.

has been read by the undersigned. It is hereby recommended for acceptance by the Faculty with credit to the amount of

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DEDICATION

This thesis is dedicated to my mother, Sandra MacDonald: the definition of strength.

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CHAPTER 1

INTRODUCTION

There are presently two general ideas about global climate forcing – one view is that the tropics are forcing global climate change while the other suggests that the high-latitudes are responsible. Because of this ongoing debate, and the poor quality of some archives, it is crucial that we extend and improve our understanding of Pacific paleoclimatic variability and the means by which we reconstruct it. Specifically lacking are long paleoclimate records from the central North Pacific, perhaps because the corals from Hawaii have not previously been demonstrated as being useful in providing long paleoclimate records. In addition many of the coral paleoclimate records generated in the Pacific have focused on reconstruction of El Niño events and on producing pre-anthropogenic sea surface temperature (SST) and sea surface salinity (SSS) records for southern hemisphere and equatorial locations (e.g., Dunbar et al., 1994; Linsley et al., 1994; Linsley 1996; Quinn et al., 1996; Quinn et al., 1998; Wellington et al., 1996; Bagnato et al., 2004; and others).

This work is unique because it focuses on constructing the first multi-decadal length paleoclimate record for Hawaii, along with assessing the usefulness of Hawaiian corals as proxies for Kona storm recurrence intervals, past SST, Pacific decadal oscillation (PDO) phase changes, and anthropogenic influences on the reef environment. An examination of isotopic and trace metal data in modern corals from Hawaii as indicators for storm recurrence intervals and past climate conditions is needed before longer environmental reconstructions can be carried out.

Today, there are limited coral paleoclimate records from the Pacific that extend beyond 100 years (Dunbar et al., 1994; Urban et al., 2000; Linsley et al., 2000a,b; among others) and there are even fewer records from the central northern hemisphere sub-tropics extending beyond ten years. The Island of Oahu is located at 158°W, 21.6°N (Figure. 1). Hawaii's corals have been understudied because the waters are not ideal for continuous coral colony growth and have not yet been shown to allow the generation of long coral records extending back to pre-anthropogenic times, like other Pacific locations (Linsley et al., 1994; Urban et al., 2000; Bagnato 2004). However, large *Porites* colonies in remote places of Hawaii have been observed and could be sampled.

Understanding past climate variability is of basic importance for understanding recent and future climate variability. In several studies it has been shown that hermatypic scleractinian corals are able to serve as proxies for such past climatic and environmental variations. Aragonite coral skeletons have been shown accurately to record annual and intra-annual variations in climate conditions such as SST, SSS, precipitation and storm recurrence intervals (for example: Dollar and Tribble, 1993; Linsley 1994; Linsley et al., 1996; Cole and Fairbanks, 1993; Gagan et al., 2000; Ren et al., 2002; and others). At present, our understanding of past climatic conditions is limited due to the lack of instrumental data. However, corals have been used extensively to reconstruct past climate conditions and are useful in extending paleoclimate variation data sets (Linsley et al., 1994; Fairbanks et al., 1997; Allison and Finch, 2004).

In Hawaii, the massive coral *Porites lobata* is abundant and is known for its surficial [topographic] undulations and rapid extension rate of around 11mm per year (Grigg, 1995). This coral species is potentially useful for generating high-resolution sub-annual geochemical analyses to reconstruct SST and SSS. However, because this massive dome-shaped species of coral grows so rapidly, it is susceptible to partial death due to storm waves, resulting in shorter records than other branching or slower-growing species of coral in a particular location. Because a coral reef is a living organism, its growth patterns are affected by environmental changes. This means that corals do not always grow straight towards the surface of the ocean, sometimes resulting in complicated growth banding patterns where the maximum growth axis does not point straight towards the ocean surface, or even upwards at all. Moreover, portions of a coral head may die, resulting in a change in the maximum growth axis, which can add complications to the stratigraphy of the coral.

Hawaiian Climate Background

Hawaii is impacted by both hurricane and Kona storm in any given year. Kona storms are low-pressure cyclones generally occurring between October and April that originate in the subtropics and off the northwest coast of Hawaii and move slowly eastward bringing increased precipitation, winds and storm swells to generally the leeward side of the Islands (Giambelluca and Schroeder, 1998). During non-storm time, northeasterly-blowing tropical trade winds prevail. During a Kona storm, the prevailing wind pattern changes with south and southwesterly winds replacing the tropical trade winds, allowing the western and southwestern sides of the Hawaiian Islands to receive the impact of the Kona storm (Rooney and Fletcher, 2004). The El Niño Southern Oscillation (ENSO) is a well-known climate phenomenon which affects the equatorial Pacific, however, it is believed to only affect Hawaii indirectly (Chu and Clark, 1999; Rooney and Fletcher, 2004), by causing a low-pressure belt of air to migrate towards Hawaii, resulting in increased precipitation and more frequent storms.

The Hawaiian Islands lie north of the area covered by the El Niño Index parameters by approximately 200km; however, it is known that ENSO affects the regional Hawaiian climate by causing an increase in Kona storms (Rooney and Fletcher 2004) and Pacific-wide hurricane frequency.

It is also known that at lower frequencies [20-30yr recurrence intervals], SST variability in the subtropical and tropical North Pacific is affected by the Pacific decadal oscillation (Mantua et al., 1997). The PDO is an interdecadal pattern that is defined by long-term fluctuations in SST and sea levels in the Northern Pacific (Mantua et al., 1997), in which regional SST becomes either abnormally warmer or cooler depending on whether the PDO is in a negative or positive phase, respectively. More simply, a positive phase of the PDO is defined as resulting in anomalously cool SST and increased sea level in the central North Pacific while, a negative phase of the PDO results in the opposite conditions. Although ENSO and the PDO climate oscillations have similar spatial climate fingerprints, with the noted exception that the PDO results in higher-amplitude SST variations in the mid-latitudes of the north and south Pacific, their periodicity [timing] is different with century PDO cycles lasting for 20 to 30 years and relatively ephemeral ENSO events persisting for only 6 to 18 months and recurring every 3 to years. In addition, the climatic effects of the PDO are most visible in the North Pacific, while only residual effects exist in the tropics; the opposite trend is seen for ENSO events. (Mantua et. al.1997; Rooney and Fletcher, 2004)

It should also be noted that Hawaii lies on the boundary between two horseshoe-shaped anomalously warm and cool pools of water in the North Pacific during any particular phase of the PDO. Although the PDO signal is more pronounced at higher latitudes, it has been shown to affect Hawaii (Chu and Clark, 1999; Rooney and Fletcher, 2004). During negative PDO phases, there is a tendency for anomalously high SST's and for the mid-latitude storm belt ridge aloft to migrate near Hawaii, increasing the number of Kona storms (Rooney and Fletcher; 2004). Their research found an increase in tropical cyclone activity in the central north Pacific between 1982 and 1997.

Hawaii Coral Summary

Aragonite coral skeleton is deposited through complex biological processes that vary depending on the SST, SSS, albedo, precipitation, cloud cover, nutrient flux, water clarity, and time of day or night, among other factors (e.g., deVilliers et al., 1995; Land et al., 1975). The symbiotic algae in the coral polyp, ultimately deposit the aragonite skeleton, and it is these organisms that are influenced by environmental conditions and allow corals to be useful as paleoclimatic proxies.

To date, very few coral-based paleoclimatic studies have been completed on Hawaii. Most of the work done on Hawaiian corals has been aimed at reef health and comparing intra-species extension rates (e.g. Grigg, 1995; Grottoli, 1999). Other studies have dealt with storm recurrence intervals, sediment transport and erosion rates (e.g., Rooney and Fletcher, 2004) and one study focused on high-resolution Sr/Ca records in *P. lobata* corals (Allison and Finch, 2004).

In this research, oxygen isotopic data were used to reconstruct SST, while trace metal data were compared to known storm events and PDO phase changes that affect Hawaii. One prevalent problem with using corals as paleoclimate proxies is the length of the usable portion of the skeleton. As stated previously, the maximum growth axis of a coral is not always in the same direction, resulting in complicated growth patterns, making sampling parallel to the maximum growth axis difficult or sometimes impossible. Because corals require a unique environment for healthy growth, consisting of warm shallow seas, with a mild current and low nutrient flux, conditions contrary to these hinder healthy coral growth and often result in a complicated or multidirectional growth band stratigraphy. Sometimes the major growth axis can appear to be horizontal relative to other adjacent density bands, producing essentially the same time-synchronous stratigraphic effect as a disconformity, rendering such areas useless for paleoclimate study.

Many recent coral studies have focused on reconstruction of ENSO and other ocean-atmosphere parameters such as the PDO (e.g., Dunbar and Wellington, 1981; Cole et al., 1993; Linsley et al., 2000a,b). It is well known that the $\delta^{18}O$ of the aragonite of coral's skeleton is a function of, both the temperature and the $\delta^{18}O$ of the seawater in which the coral grew (Swart, 1983; Winter et al., 1991; Allison et al., 1996; Ren et al., 2002). Bulk skeletal Sr/Ca ratios are also known to correlate well with local SST (Beck et al., 1992; Alibert and McCulloch, 1997; Gagan et al., 1998; Schrag, 1999; Linsley et al., 2000a,b, 2004).

In this work, both $\delta^{18}O$ and Sr/Ca were measured to assess any relationship to local and regional SST and other environmental factors that impact the reef environment. Trace element geochemistry was also investigated as a proxy for pollutants, terrestrial runoff, and as a record of disturbances on the reef environment. Having corals from opposite sides of the Island provides a unique opportunity to compare the ability of the same species of coral to record paleoclimate data and anthropogenic influences on the reef front.

The goal of this research is to develop the first multi-decadal length high-resolution isotopic record of SST and storm intervals from two different Hawaiian *P. lobata* corals. In addition to isotopic data, trace metal data were used along with instrumental measurements to calibrate the usefulness of these corals as paleoclimate proxies for the last half-century on Oahu, Hawaii, and encourage further exploration for larger and healthier corals that may allow for the generation of longer records.

CHAPTER 2

METHODS: SAMPLE PREPARATION & ANALYSES

Study Area

Oahu Island, in the Hawaiian archipelago, is located at 158°W, 21.6°N (Figure. 1). The annual averaged SST at this location is 25.5°C with an annual range of 4°C from the mean. As part of this study, Dr. Charles Fletcher of the University of Hawaii sampled two colonies of *P. lobata* near Oahu, Hawaii. In June 2002, a *P. lobata* head was drilled off of Punalu'u beach (157.881607° W, 21.576752° N) in ~10m of water. In May 2003, a *P. lobata* colony was drilled off Waikiki beach (157.881607° W, 21.576752° N) also in ~10m of water (Figures 2 and 3). Of the two coral colonies were sampled for this research, three cores were collected from Punalu'u on the NE side of the Island, and one core collected from Waikiki on the south side of Oahu [and are referred to as such in this thesis]. However, only the best core from Punalu'u (HH2), with the least complicated stratigraphy, was chosen for analysis.

Coral Collection and Preparation

After collection each coral core was washed with fresh water, dried and halved with a water-cooled masonry circular saw fitted with a diamond blade. The cores were cut into slabs approximately 7mm thick parallel to the major growth axis, following procedures similar to those developed by Dunbar et al., (1994); and Linsley et al., (1994) among others.

Each coral slab was cleaned in an ultrasonic bath with deionized water for 15 minutes to remove saw cuttings and any other particles that might have settled into the porous structure of the coral slabs. The slabs were subsequently dried in an oven overnight at 40°C and later X-rayed with a mammography medical X-ray device at a power of 31kv and a density setting of 3 for 2.5 seconds to produce radiograph images of the coral's growth bands.

The X-ray radiographs were made into X-ray positives; shown in Figures 4 and 5. The X-ray positives are used to select the most appropriate sampling track, to facilitate sampling as parallel to the maximum growth axis as possible. Outlines of the X-ray positives were traced onto over-head projector plastic sheets and placed on the coral slabs so the proposed drill track could be mapped onto the coral skeletal slab. Locally, density bands were not useful for choosing an appropriate sampling track due to irregular growth horizons.

A ruler with millimeter increments was taped to the coral slab along the identified sampling track as a guide for both sampling location and to insure uniform sample size (1x2mm per sample). For this study, samples for $\delta^{18}O$, $\delta^{13}C$, and trace metal analyses were taken every millimeter, by means of a high-speed Dremel® drill fitted with a diamond bit, aided by the use of a binocular scope. For each individual sample, a 1mm long x 2mm wide x 2mm deep increment was excavated from the sample track. Because corallites in *P. lobata* are small [0.5mm], and do not always grow parallel to the maximum growth axis, or to the sample track, each sample is an average of several corallites. After each sample was drilled, the powder was put onto a sheet of weighing paper and transferred into an appropriately labeled micro-centrifuge vial for storage. Any excess powder left in the drill track was blown out using a can of compressed air, to avoid contamination between samples. The drill bit and working surface were cleaned with isopropanol or methanol and a Kimwipe® between samples.

Stable Isotopic Analyses

For each analysis, approximately 150μg of the aragonite powder was transferred into conical glass vials that were sealed with a Kel-F® liner and silicone rubber septum and digested with 100% H_3PO_4 at 90°C in a MultiPrep sample preparation device. The liberated gas was analyzed with a Micromass Optima triple-collector mass spectrometer at the University at Albany – State University of New York. Approximately ten percent of the samples were run in duplicate. The Punalu'u coral series consisted of 654 samples with an estimated 20mm hiatus between samples 559 and 560 (it should be noted that the hiatus was not indicated with a gap in the labeling sequence between samples 559 and 579). The Waikiki series consisted of 300 continuous samples. During the Punalu'u analyses, the average composition of 126 samples of the NBS-19 standard [relative to VPDB] was –2.204 per mil for $\delta^{18}O$ and 1.950 per mil for $\delta^{13}C$, with an external precision of ± 0.030 per mil for $\delta^{18}O$ and ± 0.013 for $\delta^{13}C$. The average difference in the $\delta^{18}O$ replicates (r=126) was 0.057 per mil, and .082 per mil for $\delta^{13}C$ during the Punalu'u analyses. During the Waikiki analyses, the average composition of 58 samples of NBS-19 [relative to VPDB] was –2.200 per mil for $\delta^{18}O$ and 1.952 per mil for $\delta^{13}C$, with an external precision of ±.028 per mil for $\delta^{18}O$ and ± .012 per mil for $\delta^{13}C$. The average difference in the $\delta^{18}O$ replicates (r=58) was 0.045 per mil, and .081 per mil for $\delta^{13}C$. The $\delta^{13}C$ and $\delta^{18}O$ values for each coral sample are listed in Appendix 1.

Trace Metal Analyses

Powdered aragonite samples collected from the Punalu'u and Waikiki coral cores were analyzed for trace metal concentrations using inductively coupled plasma mass spectrometry, (ICP-MS) at Union College, Schenectady, New York under the direction of Dr. Kurt Hollocher. Unlike the isotopic analyses, the trace metals were measured on annual-averaged coral samples after determining the exact chronology using skeletal $\delta^{18}O$, density bands and mapping this chronology onto X-ray radiographs. The sampling regime used for the trace metals was a peak-to-peak method, where equal amounts of the carbonate powder from each sampling excavation between those represented by two adjacent [annual] $\delta^{18}O$ peaks were combined and a composite sample taken. Thus an average annual year that usually spanned September to August was sampled; annually averaged drilled paths varied in length from 7-13mm per year.

For Punalu'u, 50 annually averaged samples were drilled, and for Waikiki, 30. The cleaning treatment for both coral slabs was the same as that for the stable isotopic work. After drilling, 50µg of sample was weighed on an electronic balance and loaded into a specialized ICP-MS vial for a desired concentration of .05% total dissolved solids. The samples were dissolved at room temperature in a clean lab with 2ml of distilled high-purity 70% HNO_3 and 10ml of ultra-deionized water from a Barnstead triple-distillation filter system. This dissolution process was similar to that which Dr. Kurt Hollocher has employed for calcite and marl dissolutions. Great care was taken to avoid contamination, including washing the storage vials with deionized water in an ultrasonic bath and using a Teflon® coated spatula to transfer the powder to the ICP-MS vials.

An in-house standard solution was used to determine the concentration of elements in the aragonite powder. The standard solution used contained approximately 10ppm of each of the following elements: Al, Ba, Ce, Cd, Cu Fe, La, Mn, Pb, Sn, U, Y and Zn. The samples were run on a Perkin-Elmer Intercoupled Plasma Quadrupole -

Mass Spectrometer, fitted with a Dynamic Reaction Cell (DRC) for analysis of Al, Fe, and Mn because these elements required ammonia as a carrier gas rather than the standard Ar carrier gas. 10% standard replicates were analyzed, with a precision of ±2%, 1 standard deviation. The data are listed in Appendix 2.

Strontium/Calcium Analyses

Strontium/calcium (Sr/Ca) ratios of sub-annual coral samples were made following the technique of Schrag (1999) using inductively coupled plasma atomic emission spectrometry (ICP-AES) under the direction of Dr. Peter deMenocal at Lamont-Doherty Earth Observatory (LDEO) of Columbia University. For each 1mm sample approximately 100μg of aragonite powder was dissolved in 2.5 mL of 2% HNO_3, and the samples were shaken and allowed to react for several hours prior to analysis. The dissolved carbonate samples were then injected as an aerosol into a Jobin-Yvon Panaroma ICP-AES. Data were drift-corrected following procedures initially developed by Schrag (1999). It should be noted that the recent findings of P. deMenocal and B. Linsley and, found that the ratios of Sr/Ca varied depending on the amount of calcium in a sample [or sample size] (P. deMenocal and B. Linsley, personal communications). Preliminary correction factors were made by B. Linsley and P. deMenocal for samples that contained calcium concentrations greater than 20ppm. However, because the Sr/Ca data were not well correlated with SST, they were not used in making paleoclimate interpretations, the correction factors were not applied to these data. The data are listed in Appendix 3.

Chronology and Age-Model Methods

Where the coral density bands were indistinct, the coral chronology was determined using the $\delta^{18}O$ and $\delta^{13}C$ data. (Alibert and McCulloch., 1997; Linsley et al., 2000a,b). Comparison of the coral $\delta^{18}O$ results to instrumental SST data (CACSST and COADS from LDEO climate data base) from the 2x2 degree latitude-longitude grid that includes Oahu suggests that the $\delta^{18}O$ of each coral skeleton has in part recorded annual changes in SST, and thus instrumental data extending back to 1950 were used to develop the age models for the two corals. Only a small section of coral below a break in the slab had an age-model constructed without instrumental data, and is referred to, in this thesis, as the "floating" section.

The $\delta^{18}O$ data were correlated to instrumental SST data with the lowest [most negative] $\delta^{18}O$ value assigned to the warmest month of the year as a tie point, based on CAC and COADS instrumental SST data. Because instrumental data were available for almost the entire length of the isotopic data set, it was found that the actual warmest month of the year was not always the same, and thus for each year, the lowest $\delta^{18}O$ value was assigned to the actual month of maximum SST. On average that month was September, with the exception of the floating section data where no instrumental SST data were available. Using the ARAND software package (designed and maintained by P. Howell at Brown University), age assignments were interpolated between each tie point assuming constant skeletal extension rate between the points. As only a single age control point per year was used, and as coral growth was not constant, errors associated with the age assignments are possible. I estimate that the Punalu'u age model could have an error of ±6 months for some areas, while I estimate the error on the Punalu'u floating section is less than ±1 year. However, because instrumental SST data were are available for almost the entire length of the data series and it was assumed that the $\delta^{18}O$ was largely a function of SST. Using this age model, both corals had an average sampling density of 10.5 samples per year. Although corals do not grow at a constant rate throughout the year, assuming a constant time step is considered the most objective method for age model construction despite the lack of uniform growth between tie points (Charles et al. 1997).

In many studies sub-annual coral Sr/Ca has been found to be highly correlated with sub-annual SST and has been useful for chronology development (Alibert and McCulloch 1997; Linsley et al., 2000b, 2004). However, as our Hawaii Sr/Ca data contain gaps due to instrument error, these data were not compared to SST to refine the chronology. The Sr/Ca ratios also appear to discriminate against the winter months, yielding poor peaks and accentuated troughs. The Sr/Ca analyses were performed as an attempt to reconstruct an independent SST record, rather than to aid in the production of the chronology. The $\delta^{18}O$ and $\delta^{13}C$ data that are presented in this thesis are shown as a time series after being run though both the ARAND Ager and Timer program, with a constant time step of 10/yr.

CHAPTER 3

PUNALU'U

The entire set of $\delta^{18}O$ data from Punalu'u provides a good relative indicator of past SST variability from the north coast of Oahu back to 1940. The $\delta^{18}O$ from this coral show pronounced annual cycles (Figure 6). The entire $\delta^{18}O$ data set was correlated with instrumental SST from COADS and CAC and had an r=0.23.

The $\delta^{18}O$ values do appear to record the warmer [isotopically, more negative] months of the cooler years more accurately than the cooler months of the warmest years before 1976. The temporal change in this pattern occurs in 1976: the Punalu'u $\delta^{18}O$ series appears preferentially to record the warmer months after 1976, but the cooler months are preferentially recorded prior to 1976. Because the PDO (Figure. 7) is defined by abnormal SST's in the North Pacific, and because these corals appear to record warmest months more accurately than cooler months, this observation suggests that the coral $\delta^{18}O$ are subordinate to the PDO phases, and possibly related to factors separate from changes in SST.

In 1976 the PDO index underwent a cyclic change from a negative to a positive phase (Figure 8), which coincides well with the previously discussed Punalu'u corals $\delta^{18}O$ bias seen in Figure 6. The change in the Punalu'u $\delta^{18}O$ from discriminating against the summer months to preserving summer months suggests that the coral is being strongly influenced by some component of the PDO. As the PDO changes from negative to positive [warmer to cooler SST's] on Hawaii, the $\delta^{18}O$ values in the coral are able to mirror the instrumental SST's more accurately than times during the negative PDO phase. This might be in keeping with the findings of Fairbanks (1997) in that an ambient increase in SST causes a more stressful environment for the coral.

Because the Punalu'u $\delta^{18}O$ data show a change in bias occurring around 1976, the Punalu'u data were divided into two parts, pre-1976 and post-1976 and the two data sets were separately correlated to SST (Figures 9 and 10). Figure 7 shows the warmest and coolest month from each year before 1976, during a negative [higher SST] PDO phase, plotted against SST with an r=0.65. Upon closer inspection, it can be seen that the data appear to fall into two scattered groups, indicating the coolest months and warmest months grouped together. During this negative PDO phase, the ambient SST at Hawaii would be increased slightly, possibly providing a stressful environment for the coral to grow in, resulting in more dense bands, or a prolonged dense band within a given year. A bias against the warmest months of the warmest years is also seen during these negative phases.

Figure 10 shows the warmest and coolest months for each year after 1976, during a positive [cooler SST] PDO phase. These data, with an r=0.82, plot into tighter groups than the data that were recorded during the negative phase of the PDO. I infer that it is this drop in SST that provides a more desirable environment for the coral and allows SST to be recorded more accurately by $\delta^{18}O$. The difference in these two figures indicates that the PDO has a significant impact on Hawaiian corals and their ability to accurately record past SST.

The sampling track chosen for this coral was aligned with a topographic bump along the maximum growth axis, and resulting in the sampling of skeleton powder that records isotopic temperatures more than 1°C higher and accrete high-density skeleton about 2 months earlier than isotopic values taken from a low (or valley) topographic area of the coral (Cohen and Hart, 1997).

In corals, the density bands are often formed annually, and it has been observed that bands from both the same year and adjacent years vary individually in density. At this location the high density bands were deposited during the summer months, perhaps due to an increase in ambient water temperature and subsequently a less suitable environment for growth, as suggested by Fairbanks et al., (1997). However, it was these more dense bands that produced $\delta^{18}O$ values that were in best absolute agreement with the instrumental SST data.

Because sampling was done at constant 1mm increments, more samples were retrieved per year from the time when the coral was growing fastest, in this case winter. A similar reduced calcification rate [during increased growth rate] was observed in a Fijian *Porites* coral however at Punalu'u, the denser summer bands record past SST more accurately than do the less dense winter bands. Fijian summer average SST is 27.2°C (Bagnato et al., 2004), whereas the average Hawaiian summer SST is 25.5°C, almost a two degree difference that could be recorded by the tropical and sub-tropical corals respectively. Just as corals become stressed due to an increase in the ambient SST, corals also become stressed by a significant decrease in SST. It is possible that because the Hawaiian waters are, on average, almost two degrees cooler than in the tropics, the increase in ambient water temperature for Hawaiian corals during the summer does not have the same stressful effect as seen in the studies of (Fairbanks et al., 1997; and Bagnato et al., 2004). Rather, the negative phase of the PDO may have another component associated with it other than SST that cause stress to the corals. The densest Hawaiian summer bands tended to yield more pronounced $\delta^{18}O$ values, during a positive PDO phase only. The increase in the sub-tropical Hawaiian summer SST's to around

27°C rather than an increase to 29°C, which is common in the tropics may not be as stressful to the coral as in more tropical locals. Both the Hawaiian and Fijian corals were observed to have produced the densest bands in the summer, but the accuracy of the two $\delta^{18}O$ records of summer SST's are discrepant: the $\delta^{18}O$ from the densest Hawaiian bands followed SST's more closely than the less dense bands, while the opposite effect was observed for Fijian corals. This suggests Hawaiian corals require an increase in SST to around 27°C to most accurately record SST's, while an increase in SST to 29°C, such as at Fiji, may stress the coral too much for SST to be recorded. If true, it would support the idea that components other than SST during the negative phases of the PDO cause Hawaiian corals stress and thus prevent reliable preservation of data for the warmest months during times of increased SST.

Figure 11 shows that during the positive phase of the PDO, from 1980-2002 the minimum and maximum $\delta^{18}O$ values at Punalu'u generally coincide temporally with maximum and minimum instrumental SST's respectively, but occasionally lag them. Figure 12 shows that the Sr/Ca analyses of the Punalu'u coral are only in partial agreement with the oxygen isotopic data, and do not appear to be a reliable proxy for SST reconstructions at this location. These findings are in keeping with those of deVilliers et al., 1995.

Punalu'u Trace Metal Data

Annual averaged trace metal samples were analyzed as a record of environmental disturbances and possible anthropogenic activity. Trace metals of interest are shown in Figure 13. Three elements with interesting signals are Fe, Al, and total Pb (a weighted average of Pb 206, 207 and 208), with Al and Fe being highly co-variant and tending to increase sharply at many strong storm events (Figure 14). It should be noted that in the coral slabs, periodic dark and light brown colored bands were observed in the coral's slabs that were generally coincident with the pattern of growth of the skeletal bands, possibly indicative of silt or clay trapped in the corals skeleton.

Storm events, both Kona and other significant storms, appear to be reflected in the $\delta^{13}C$ and trace metal data on Figure 14. Here the data are displayed as annual averaged $\delta^{13}C$ samples with annual averaged Fe and Al concentrations. The causes of the variations in $\delta^{13}C$ values for Punalu'u are not as well understood as those for $\delta^{18}O$, however $\delta^{13}C$ appears to be related to storm activity and the resultant nutrient flux to the reef environment. Coral reefs require a clear water column for photosynthetic algae to survive, however, nutrient spikes to the reef environment also affect the ability of the corals polyp to produce a skeleton. Studies have shown that ocean dwelling photosynthetic organisms such as phytoplankton, are affected by Fe as a nutrient (e.g., Johnson et al., 2003). This suggests that the elevated Al and Fe values were due to sediments or flocculated clays being disturbed on the reef front as a result of increased storm activity and or increased runoff as a result of storm-induced precipitation, and that these sediments and clays were deposited on the coral mucus membrane (Wild et al., 2004).

Of particular interest is the spike in Al, Fe, and $\delta^{13}C$ in 1963, when two back-to-back Kona storms hit Oahu just two weeks apart. Reports of these two storms recall that the first storm lasted two days and brought winds of up to 84mph, deepwater wave heights of 3m, and caused extensive erosion. The second storm, 14 days later, lasted for

3 days and brought increased precipitation, 2m wave heights and eroded beaches as much as 50ft in some locations.

Increased biologic activity of the coral polyp generally is reflected in a coral skeleton by decreased carbon isotope ($\delta^{13}C$) values with an increase towards more negative values (Rubinson and Clayton, 1969; Swart, 1983; Winter et al., 1991; Allison et al., 1996). With Fe being a well-known nutrient for both the open ocean and the reef environment (Sholkovitz and Shen 1995), it is suggested that the decrease in carbon isotopic values which generally coincides with the increase in Al and Fe, is due in part to the Fe behaving as a nutrient to the coral, resulting in increased biologic activity, and thus more negative $\delta^{13}C$ values. The alternating brown layers observed in the coral slabs are silt layers incorporated into the stratigraphy of the coral. It was not impossible to accurately correlate the brown bands in the coral's skeleton with any increases or decreases in the trace metal data or storms because annual-averaged samples were taken, thus incorporating several light and dark bands together in the averaged sample. This makes it impossible to know for certain if the increases in the trace metal data are directly correlative to the brown coloring seen in the coral core lattice.

Throughout the time series, Fe and Al concentrations were coherent, and frequently, but not always the concentrations increase sharply at times that coincide with many strong storm events (Figure 14). This suggests that the increases in Fe and Al concentration may be due to storms, producing both waves and increased precipitation. Waves capable of disturbing sediments may produce flocculated Al-rich clay particles that settle on the coral mucus membrane, also becoming trapped in the coral polyp (Wild et al. 2004). Heavy rains might also increase erosion run-off of terrestrial Fe sources.

It should be noted that the ratios of Fe/Al are highly variable throughout the time series and likely suggest more than one source for these elements in the coral. Figure 14 shows an increase of Fe and Al in 1952, however the Al concentration is greater than the Fe by a magnitude of approximately 10. This suggests that there is more than one source of Fe and Al. Marine clays generally have a higher concentration of Al than Fe, and if disturbed by storm waves could be a likely source of Al to the reef environment. However, if marine clays were the only source of Al and Fe to the reef environment, the ratios of Fe/Al would be expected to be constant. Likewise, much of the homogeneous basaltic terrestrial sediments of Oahu contain Fe and Al in their mineral assemblages, that when weathered could form iron-hydroxides and be transported to the reef environment by run-off. Probable terrestrial sources of Fe that could be weathered and transported are olivine, amphiboles and some pyroxenes, where probable sources of Al are plagioclase, igneous amphiboles and spinel (D. Burkhard, 1993). The down-core variance in the ratios of Fe/Al suggests that several sources of Fe and Al are possible, and not just directly related to flocculated clay particles. However, both terrestrial and marine sources of Fe and Al would be introduced to the reef environment by storms producing increased waves to disturb sediments, and increased rainfall and subsequent run-off of eroded sediments.

Trace lead (Pb) in the environment is well known to be a product of solid waste incineration, and leaded gasoline combustion (Chilrud et al., 1999). The Punalu'u coral shows a significant drop in total Pb between 1976 and 1978, that coincides well with the phasing out of leaded gasoline (Thomas, 1995). Although leaded gasoline was still commercially available in the United States until the early 1980's, it began to be phased out starting in the mid 1970's. There are other possible sources of Pb, including many industrial operations such as leather tanning, lead arsenate production, and the production of asphalt, in addition to inappropriate disposal of lead-containing substances and mine-tailings (Spliethoff and Hemond, 1996; David, 2003). However, there is little evidence of these types of industrial processes near Oahu that would affect Punalu'u. In addition, if other sources such as asphalt were contributing to the Pb flux to the reef environment, then the decrease in Pb concentration after 1976 would not be so pronounced, as asphalt roads were not phased out in 1976.

On Oahu, it is assumed that the two main pathways for Pb to be introduced to the reef environment are in the aerosol form, and as a particulate Pb, or adsorbed to clays or organic matter. The Pb concentrations also have a nearly 10-year cyclic pattern, until 1976 (Figure 13). Although it is not known why this pattern occurs, I suggest that it is due to excessive run-off, which is due in part to very strong storms that tend to occur around every 10 years on Oahu. Kona storms bring significant amounts of precipitation to Oahu, and likely increase run-off and terrestrial erosion. Table 1 shows major Kona storms to hit Hawaii: there were major (magnitude 4) Kona storm for the years 1945, 1955, 1967 and a hurricane in 1976, most of which coincide well with the large near 10-year cyclic spikes in Pb. However, this is only one idea proposed for the cyclic variations in Pb.

Figure 13 shows Pb plotted with Fe and Al. Although there is a prominent decrease in Pb concentration from 1978 to 1988, Pb concentration does increase again in 1989 and again in 1992. Because aerosol deposition rates have not been quantified in this time period, it is assumed that aerosol deposition would provide a background level of Pb to the reef environment. Run-off however, would be directly affected by increased precipitation. Although the overall concentration of Pb decreases significantly after 1976, some peaks of Pb are still seen in the 1990's that coincide well with peaks in Fe and Al.

CHAPTER 4

WAIKIKI

The $\delta^{18}O$ data from the Waikiki coral show a clear annual cycle, although there appears to be a bias towards the summer months, during which oxygen isotopic data more closely match instrumental SST values (Figure 16).

Unlike the Punalu'u coral, which was sampled mostly along a growth axis of a topographic bump, the Waikiki sampling track began at a topographic low, but then intersected a topographic high. Figure 5 shows why it was not possible to begin a sampling regime along a topographic high on the Waikiki coral because the annual bands along that topographic high continued off to the right, off of the coral slab, making it impossible to sample along that axis.

The Waikiki $\delta^{18}O$ values appear to switch their ability to capture the annual SST signal from a winter month bias to summer a month bias. Because the Waikiki coral record is relatively short [28yrs], the record does not extend back far enough to have experienced a PDO phase change from negative to positive. The Waikiki coral record presented is only for a positive phase of the PDO, with the exception of very brief changes to negative phases in the 1990's (Figure 8). The Waikiki coral does provide a relative indication of SST, but some of the $\delta^{18}O$ data points are discrepant with the instrumental SST data, while other $\delta^{18}O$ values mirror the instrumental SST data remarkably well. Discrepancies between the isotopic values and the SST values are easily spotted in Figure 16, particularly in the winter months between 1986 – 1996. The instrumental SST data frequently indicate temperatures 1.5 - 2°C cooler than the $\delta^{18}O$ indicated for the winter months. Yet, the Waikiki coral also offers excellent records of summer SST in two peaks, particularly '89 and '84, with $\delta^{18}O$ peak profiles that follow the SST data quite well. The correlation of the Waikiki data has an $r=0.20$.

The $\delta^{13}C$ values for Waikiki shows no coherent relationship (Figure 1) and, in addition, the $\delta^{13}C$ do not appear to correlate with storm activity or potential sediment flux on the reef environment.

Waikiki Trace Metal Data

Annual averaged heavy trace metal samples were analyzed as a potential record for environmental disturbances and possible anthropogenic activity. Figure 17, shows annual-averaged values for Al, Fe and $\delta^{13}C$. In this case, more negative $\delta^{13}C$ values do not coincide with relative increases in Al and Fe, and trace metals data do not show any coherent relationship to Kona storms, SST changes, or PDO phase changes.

With the Waikiki location being on the southern side of Oahu, it was thought that the Waikiki coral might be subject to more storm activity, especially from hurricanes that are traveling north. This assumption has proven either to be incorrect, or the Waikiki coral has not recorded these events. The Waikiki trace metal data do not show a correlative relationship between metals and storm events. Although it is not clear why the Waikiki coral does not show a clear record of storm events, I infer that the low topography of the Waikiki near-coastal area and the relatively unprotected bay contributed to a more stressful environment, and thus a less clear record of influences on the reef. In addition the Waikiki time series is not long enough to extend back beyond 1975, which prevents us from determining whether elevated Pb concentrations existed before 1976, or during a significant PDO phase change.

CHAPTER 5

PUNALU'U & WAIKIKI COMPARISON

One goal of this research was to reconstruct a paleoclimate record for Oahu using *P. lobata* as a proxy for SST and anthropogenic effects on the reef environment while evaluating the usefulness of Hawaiian *P. lobata* corals for paleoclimate study. In addition, focus was placed on trying to assess the reproducibility of environmental parameters between two different coral colonies located on opposite sides of Oahu. Linsley et al., (1999) found that although corals of the same *Porites* species growing in the same location can have different absolute $\delta^{18}O$ values, because skeletal carbonate is a not produced in equilibrium with seawater, they can have comparable isotopic variance. This also appears to be the case with the Hawaiian corals: the Waikiki and Punalu'u corals provide discrepant but comparable $\delta^{18}O$ results, (Figure 18, where the two time series are plotted on the same scale). The Punalu'u coral has an average $\delta^{18}O$ value of –4.335 per mil for all data points analyzed, which is lower than the Waikiki $\delta^{18}O$ average of –4.284 per mil. Figure 19 shows both the Punalu'u and Waikiki $\delta^{18}O$ data centered on zero – accomplished by subtracting the average $\delta^{18}O$ value from each coral's respective time series. As suggested by Linsley et al., (1999), subtracting the average $\delta^{18}O$ all of the $\delta^{18}O$ values so they are centered around the mean facilitates comparison of the records and allows for examination of common variance in each time series. In this research, in particular, reproducibility is of great concern because it is necessary to demonstrate that reliable paleoclimatic records can be extracted from Hawaiian corals.

Because the correlation of $\delta^{18}O$ to SST is of basic importance for understanding past climate, isotopic time series were constructed for the two corals. It is clear that there is reasonable agreement between the $\delta^{18}O$ and instrumental SST for both corals, however

I suggest that the Punalu'u $\delta^{18}O$ are largely influenced by both PDO phases and possibly factors such as salinity, or wind stress, other than SST, related to the PDO.

Because the corals grew in a different geographic environment, they were also exposed to different set of environment conditions, specifically differing coastlines. Waikiki, on the south side of Oahu, is a more arid environment, with less runoff, and more Kona storms, while Punalu'u receives significantly more precipitation and terrestrial run-off, being at the base of a steep mountain range. Each coral faithfully recorded annual SST signals for their environment, and were in good agreement [isotopically] with each other, however the two corals did not show reproducible trace metal results. The Al and Fe concentrations in the Punalu'u appear to be a good indicator of storm activity and increased run-off to the reef environment and the trace metals tend to relatively mirror the $\delta^{13}C$ data. However, disappointingly, the Waikiki coral does not show similar results to the Punalu'u coral.

CHAPTER 6

CONCLUSIONS

This work has demonstrated that Hawaiian *Porites lobata* corals have potential as independent proxies for SST and storm event reconstruction. Moreover, this research provides the first multi-decadal sub-annual $\delta^{18}O$ coral record from Hawaii, for the central North Pacific.

There are several main conclusions that result from this research. Two independent paleoclimate reconstructions for SST were constructed using $\delta^{18}O$ data from the two Oahu corals demonstrating that Hawaiian corals, despite growing in relatively cooler waters, are still able accurately to record environmental parameters. Unlike corals in other studies and locations, the Hawaiian coral's densest skeleton recorded the warmest months more absolutely than the cooler months. These findings are an encouraging first step towards extending the paleoclimatic records from the sub-tropical central north Pacific.

The $\delta^{18}O$ time series for the Punalu'u coral showed a clear bias against preservation of the warmest months prior to 1976 and a marked change after 1976, where the coral was not biased against the warmest months. This change in bias coincides exactly with timing of the PDO transition from negative to positive phase. It is also clear that these Hawaiian corals appear to record the warmer months of the cooler years more accurately than the warmer months of the warmer years. It is this behavior of the corals that suggests the corals are subordinate first to a component associated with negative phases of the PDO rather than solely SST (ironically, since SST is what defines the PDO).

Trace metal analyses of the Punalu'u coral suggest that there is a correlation between storm disturbances on the reef environment and a subsequent increase in the concentration of certain marine and terrestrial metals. The increase of nutrient metals to the reef environment also appears to foster biologic activity, resulting in lower $\delta^{13}C$ isotopic values, which are associated with synchronous increases in metal concentrations. Trace metal data also show a significant decline in Pb concentrations that clearly coincides with the phased elimination of Pb in gasoline, suggesting that the predominant source of Pb to the reef front in Hawaii is from the combustion of leaded gasoline.

Hawaii falls well north of the El Niño index parameters, as the primary zone of ENSO-influenced SST variability is between 5°N and 5°S latitude. Although the Hawaiian corals do not suggest a direct influence by ENSO, the coral $\delta^{18}O$ and trace metal data suggested that ENSO has an indirect effect on Hawaii that manifests itself by times of increased storm frequency. The Hawaiian corals do indicate a direct influence from the PDO that affects the Pacific much farther north than ENSO.

The two *Porites* corals do demonstrate their ability to record relatively similar SST's although their absolute individual $\delta^{18}O$ records differed slightly. The corals do not prove to be useful for between colony trace metal reconstructions dealing with storm events through incorporated trace metals. This may be due to the very short Waikiki record.

This research provides a promising first step in utilizing Hawaiian corals for paleoclimate and storm reconstruction. With Hawaii being virtually the only location in the central North Pacific, it is crucial that Hawaiian corals be proven reliable for paleoclimate reconstructions. Future research should focus on sampling the already observed larger and healthier *Porites* corals from Hawaii, both to add to other existing Pacific paleoclimate records and to address the more specific findings in this initial study.

Two areas of particular interest that further research should focus on are investigating the Hawaiian coral's apparent response to PDO phase changes, and their preference to record the summer months more accurately even though they grow more slowly. Given the initial findings of this research, I suspect that we have not yet seen the full potential of Hawaiian corals.

CHAPTER 7

TABLES AND FIGURES

TABLE 1. MAJOR KONA STORMS.

Table 1. Major Kona Storms				
				Magnitude
				0 = no impact in Kihei
				1 = minor impacts, last up to a season
				2 = moderate, impacts last for year after event
				3 = heavy, impacts last for 5 years
			Duration	4 = very heavy, impacts last for 20 years after event
	Source of		on Maui	
Date	Data	Magnitude	(days)	
11-12, 1939	CR	4		Kona conditions prevailed from late Novemeber into early January as a series of low pressure areas moved through the state.
3/1944	CR	4		South and southwesterly Kona winds blew an unusually large number of hours during March, setting a monthly record for the percentage of wind from this quadrant.
11/1945	CR	4		Kona winds prevailed, with twice the normal percentage of southerly winds recorded in Honolulu.
10/1946	CR	4		A particularly long period of Kona weather lasted from the 6th through the 15th.
2/1951	COE	Unknown		This Kona is described as causing heavy beach erosion along Kihei Beach, and damaging the highway there.
12/20/1955	COE	4	2	This Kona event lasted a minimum of 33 hours, with a wind speed of 25 knots, deepwater wave height of 13.4 ft and period of 11.0 seconds, coming from the west-southwest.
1/17/59	COE, SD	Unknown	1	This severe frontal passage had deepwater wave heights of 14 ft and periods of 9.6 seconds, coming from 247degrees. Winds exceeded 35 mph, with gusts to 100 mph. Trees, many buildings, boats, and crops were destroyed. COE report says this event caused erosion damage to Kihei Beach.
11/1/1961	SD	Unknown	3	A several day Kona event brought heavy rain and high winds to the islands, causing extensive damage to the islands of Maui, Lanai, and Molokai. Precipitation totalled over 26 inches for some areas of Maui.
1/7/1962	COE	4	1.5	Windspeeds were recorded at 25 knots with deepwater wave heights and periods of 13.6 ft and 1.1 seconds and coming from the southwest, for a minimum of 25 hours.
1/17/63	COE, SD	Unknown	2	Strong winds, rain, and waves with deepwater heights of 12 ft and periods of 9.8 sec., are reported for this frontal passage that casued erosion to Kihei Beach. There was extensive damage to roads, buildings, trees, crops, and power lines. Winds up to 84 mph were recorded.
1/31/1963	COE, SD	Unknown	3	This Kona had a minimum duration of 63 hours, and deepwater wave height and period of 7.2 ft and 9.8 seconds, from the south-southwest estimated for an area 40 nm south of Kihei. However, winds up to 84 mph were recorded. Described as one of the worst storms on record, it caused severe beach erosion as well as damage to houses, trees, crops, power lines, etc. Local winds in excess of 40 mph, and waves coming from the west-southwest, 10 ft high and breaking 300 yds offshore were observed in Kihei. This storm, in conjunction with a frontal passage on January 17th, caused the shoreline to recede as much as 50 ft in places. Homeowners spent $50,000 on emergency measures to reduce erosion.
1/9/67	SD	4	1	Strong winds associated with a frontal passage damaged trees, and some buildings. Boats were damaged by wind and waves, even in Keehi Lagoon.
2/24/68	SD	Unknown	3	Strong wouthwest winds from a slow moving cold front damaged trees, buildings and crops. Winds to 62 mph recorded. Wind-blown surf rolled into the Kona Hilton Hotel and sank a boat.
1/13/70	SD	Unknown	2	Severe south to southwest winds in front of a severe cold front caused the greatest dollar damage ever reported in the state up to that time for a single weather event. Many trees were knocked down, buildings detroyed, etc. Winds up to 93 mph. were recorded.

TABLE 1. MAJOR KONA STORMS.

2/5/76	SD	Unknown	2	An unusual Kona storm approached from the northwest then went back to the northeast, accompanied by high wind and surf, and flooding. Strong southwest waves broke a sloop loose of its moorings in Kihei & washed it ashore and other leeward shorelines had waved damage. Winds above 90 mph were recorded as well as heavy rain.
1/8/1980	MN, AR	16		Called a 30-100 year storm, this event was actually caused by 2 low pressure areas one after another. Kihei was cut off from the rest of Maui and damage there was extensive. Cars washed out to sea near Suda Store, 4-5 boats were destroyed in Kihei, and beaches from Kihei to Lahaina lost sand. Each of the three Kamaole Beach Parks lost sand and all of it washed out of Kamaole #2. Kihei Road was undermined and a house at Keawakapu lost land. Kihei appears to have been the hardest hit area on Maui.
1/13/85	SD	4	2	An eastward moving low north of the islands caused strong southerly winds but mostly minor damage. Several buildings and crops were destroyed.
12/24/1984	SD	4	2	This two-day Kona storm caused minor wind and flooding damage to all the major islands. Surf damage and beach erosion were reported from Oahu's north shore.
12/11/1987	SD	4	7	This low pressure system developed west of the islands and remained there for a week, causing associated cloud and showeer bands to move into the state on several occasions dropping heavy rain and causing widespread flashflooding. Some scattered wind damage occurred from strong upper southwesterlies.
11/4/1988	SD	Unknown		A low pressure system west of Kauai caused strong southerly and southwesterly winds gusting to 40 to 50 mph. The winds damaged crops, property and overhaed wires and beached several boats. Extensive flooding occurred on Maui and Kauai. The low moved first eastward across the state and then westward back across it.
12/5/1988	SD	4		A Kona develooped west of the islands and moved eastward across thestate, dropping particularly heavy rain on Maui, causing flooding and road closures on West Maui and in Kihei. Strong southerly winds gusting to 50 mph caused minor damage along leeward coasts.
2/13/1992	SD	4		A Kona developed close to the main Hawaiian Islands and moved east-northeast north of the state, producing locally heavy rains. Gusty southwest winds accompanied the storms passage. Southwesterly winds continued for most of the month.
2/24/1997	HSB, HA	4	3	A several day event, this Kona storm had locally heavy thunderstorms and showers and high winds. It caused damage from Kauai to the Big Isalnd, especially on the southern islands.
				Data Sources
			AR	Anecdotal Reports
			COE	Detailed Project Report, Shore Protection, Kihei Beach, Maui, Hawaii (1967), Dept. of the Army, Corps of Engineers, Honolulu, Hawaii, 55 p.
			CR	Climatological Reports, U.S. Dept. of Agriculture, Weather Bureau, Hawaiian Section of the Climate and Crop Service, 1905-1948.
			HA	Honolulu Advertiser
			HSB	Honolulu Star-Bulletin
			MN	Maui News
			SD	Storm Data and Unusual Weather Phenomena, (1959-1998), Monthly Climatological Summaries, National Weather Service.
			TC	Shaw, S.L.(1981) A History of Tropical Cyclones in the Central North Pacific and Hawaiian Islands 1832-1979, Natioal Weather Service, 137 p.
				Adapted from Dr. Charles Fletcher 10/04

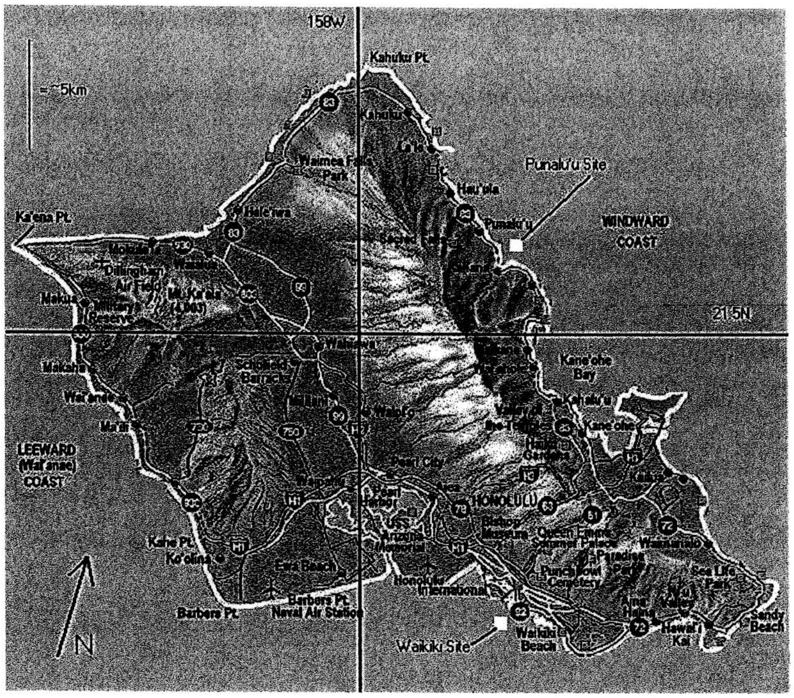

Figure 1. Location Map: Oahu, Hawaii. 158W, 21.6N Pacific Ocean. Two coral locations are shown with white squares. Punalu'u location shown on the Northeast side of the Island, and Waikiki is shown on the Southern side of the Island. Arrow points to magnetic north.

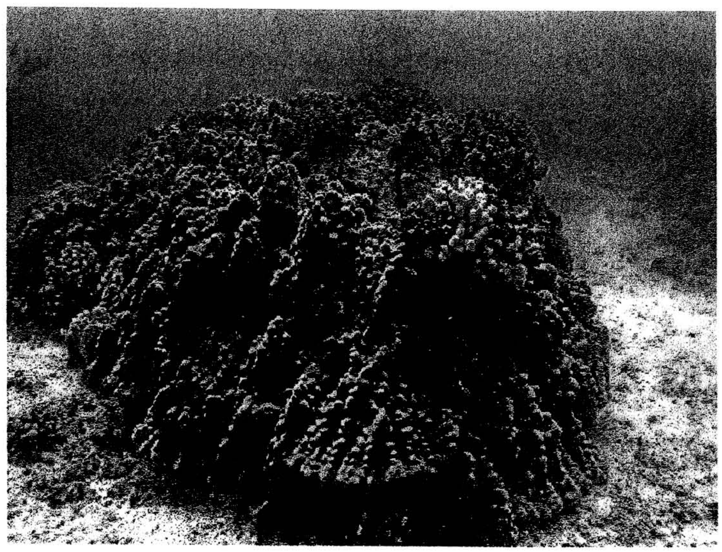

Figure 2. An underwater photo of the Waikiki coral before drilling – approximate scale is 2m high and 3m wide. Courtesy of Dr. Chip Fletcher University of Hawaii.

Figure 3. Aerial image of Waikiki Beach – location of the Waikiki coral is shown with a small white asterisk, and an arrow.

Figure 4: Punalu'u X-Ray positive with sampling track shown.
Entire drill track length was 657mm

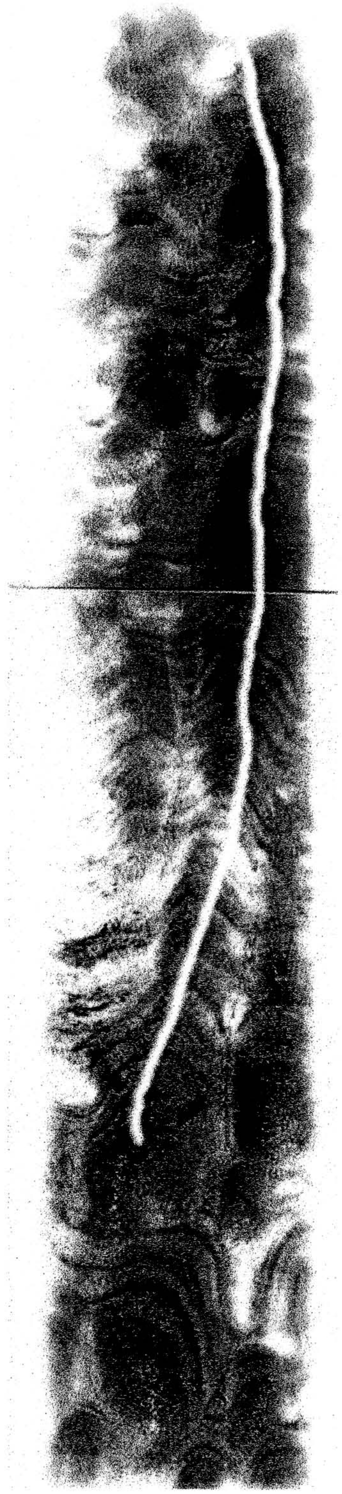

Figure 5: Waikiki X-Ray positive with sampling track shown. Entire drill track length is 300mm.

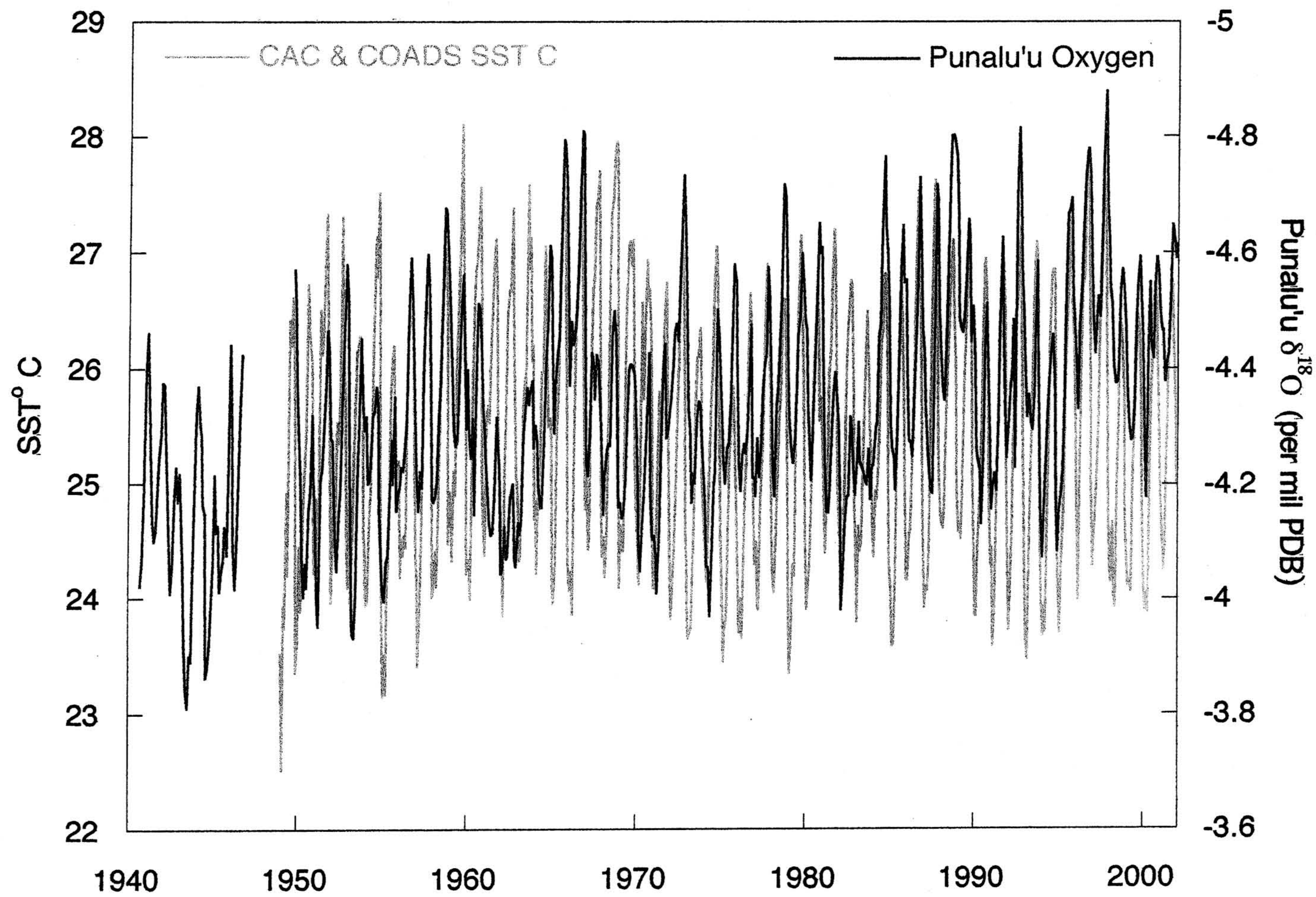

Figure 6. Punalu'u $\delta^{18}O$ vs. SST 1940 - 2002

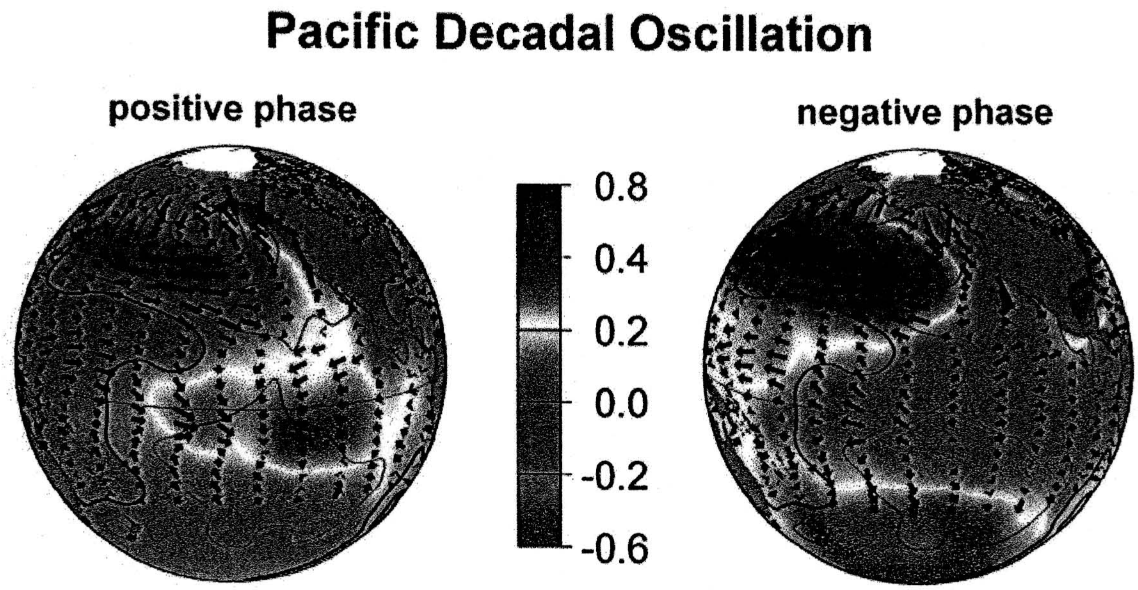

Figure 7: Pacific Decadal Oscillation phase diagram. Units are in °C. Upon close inspection, the Hawaiian archipelago can be seen between the cool and warm pools of the positive phase of the PDO.

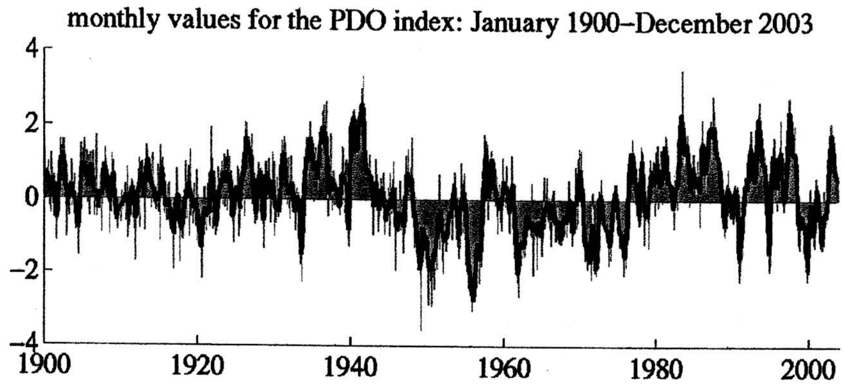

Figure 8: Monthly values for the PDO index: January 1900 – August 2004.

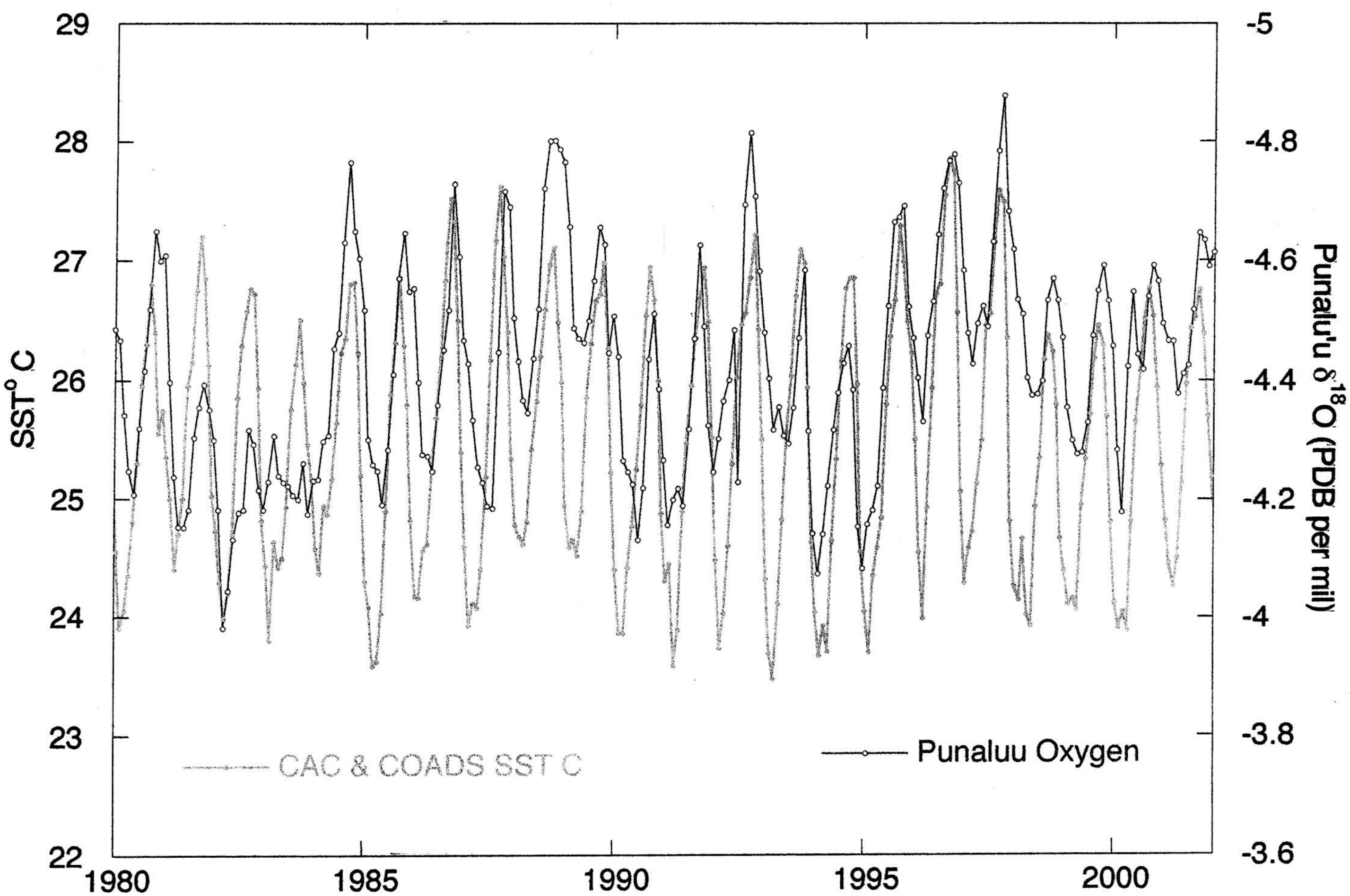

Figure 9: Punalu'u $\delta^{18}O$ vs. SST °C 1980 -2002

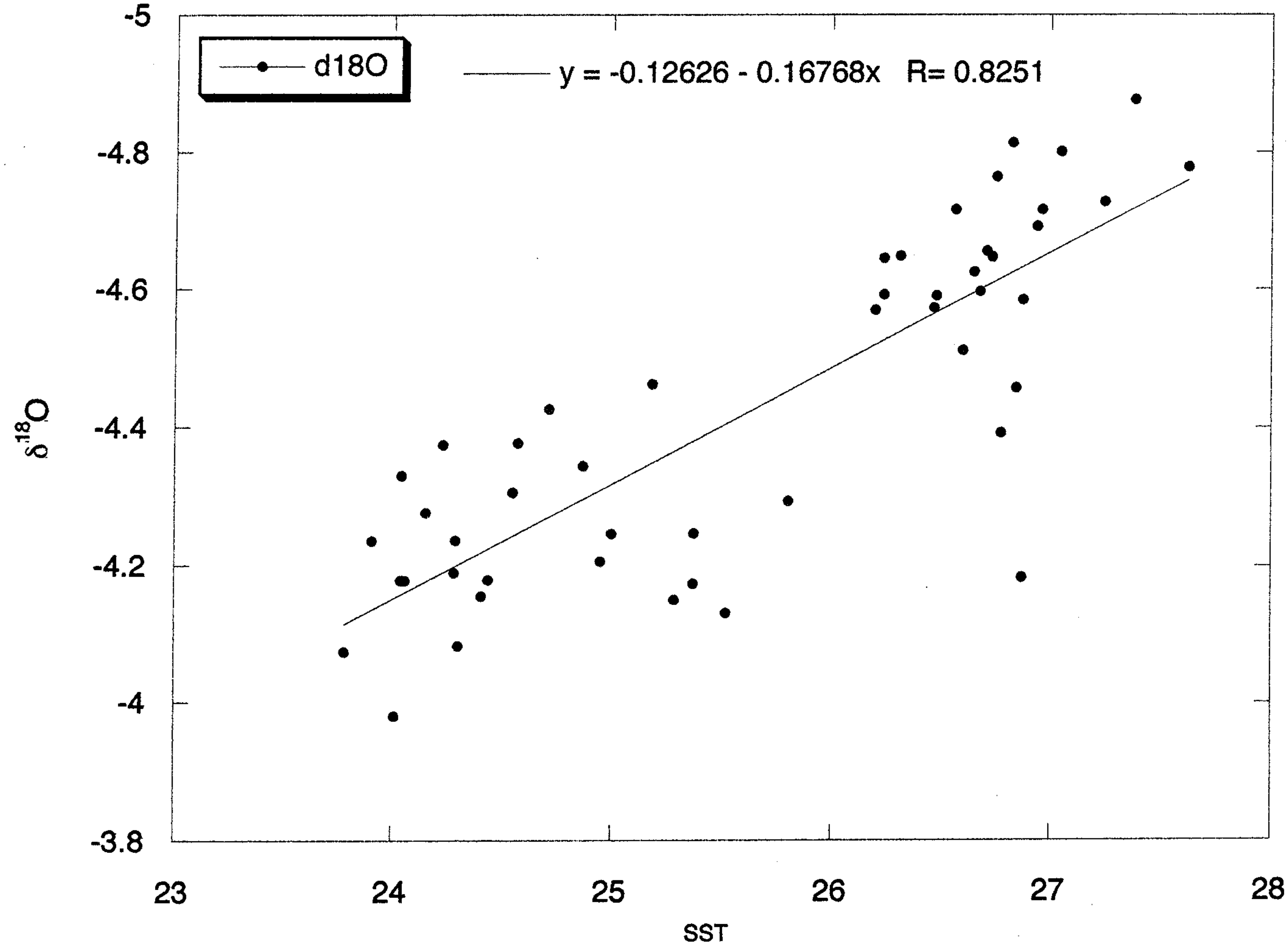

Figure 10. Warmest and Coolest $\delta^{18}O$ values per year post-1976.

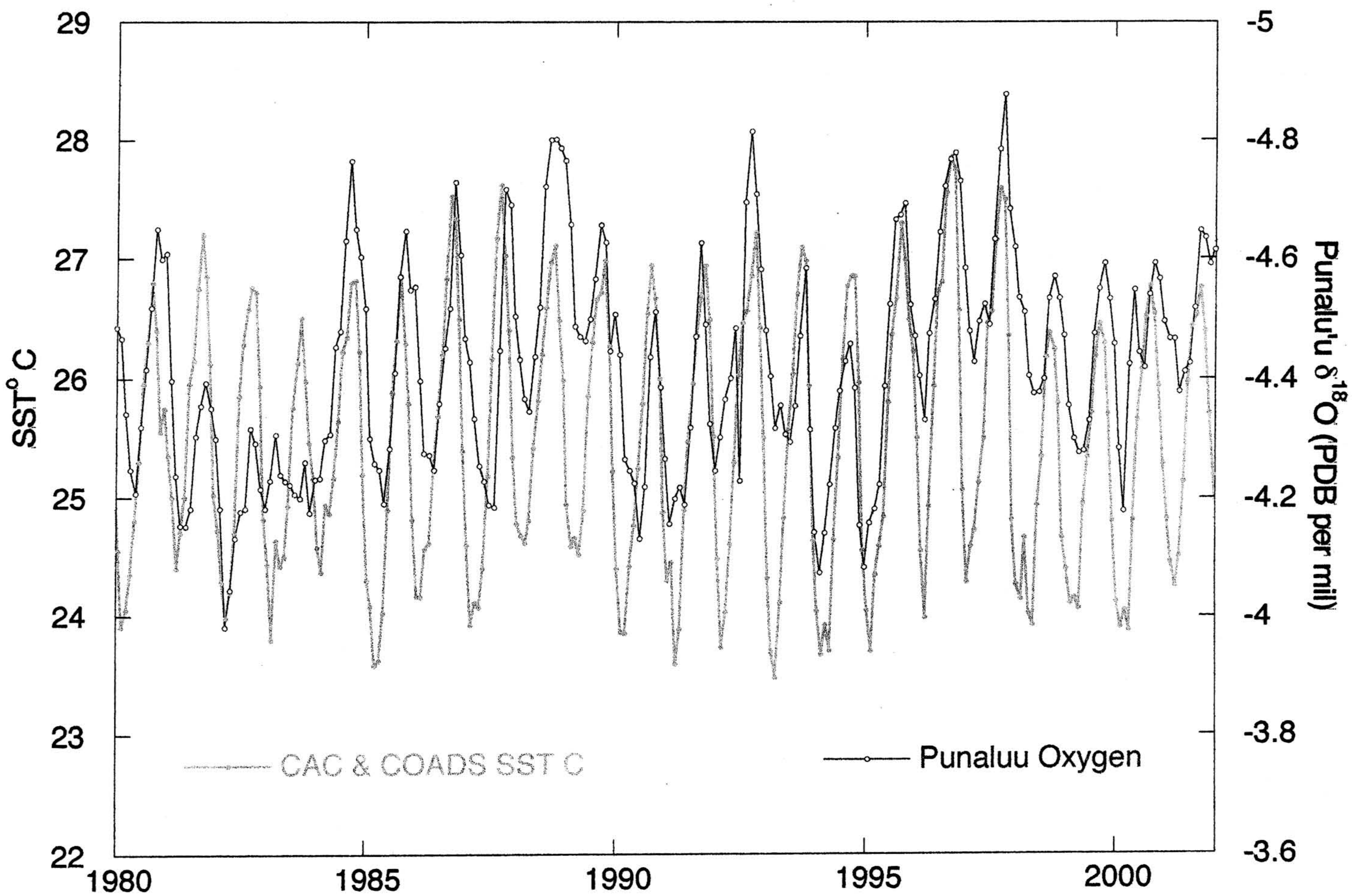

Figure 11: Punalu'u $\delta^{18}O$ vs. SST °C 1980 -2002

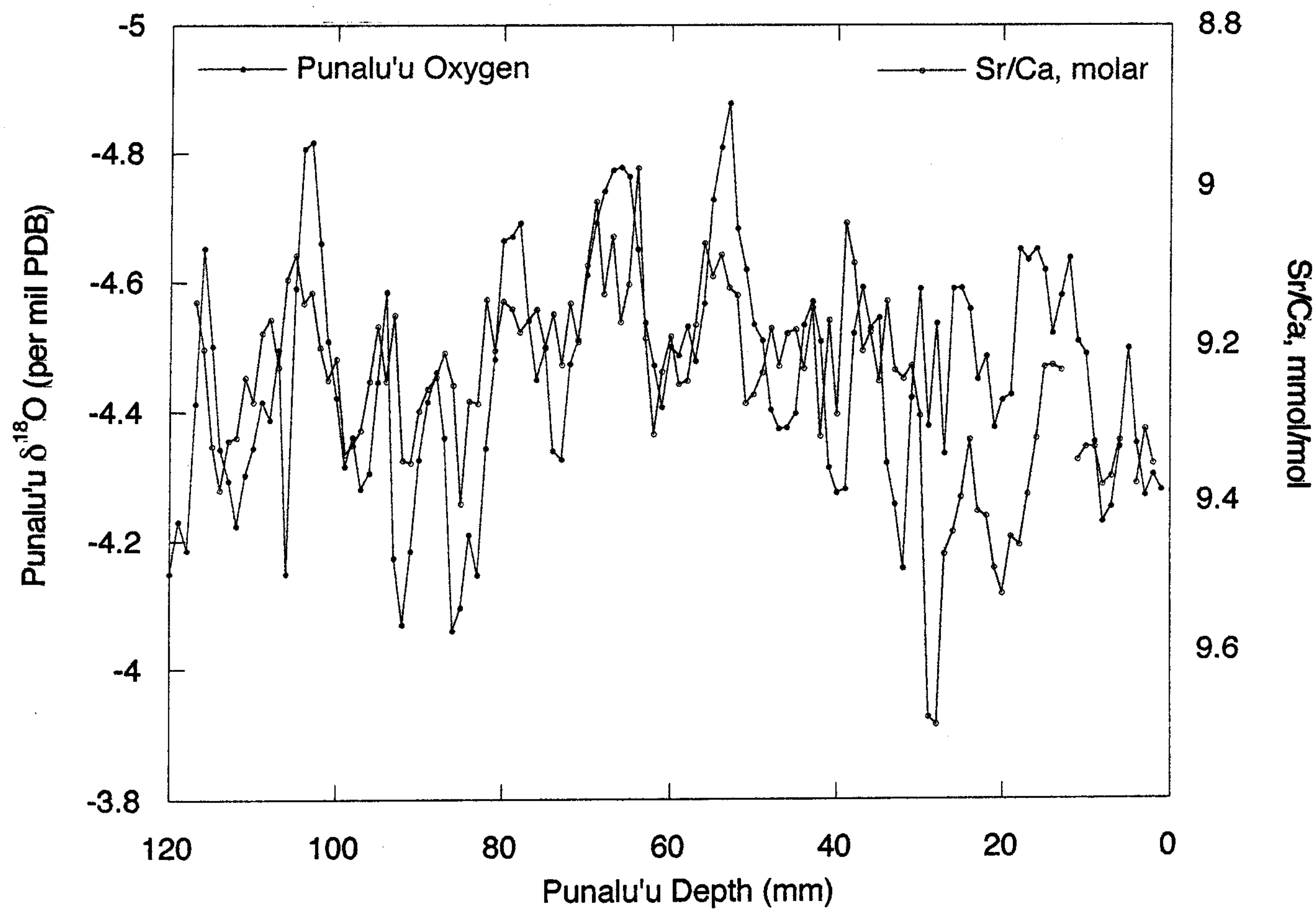

Figure 12. Punalu'u $\delta^{18}O$ vs. Sr/Ca

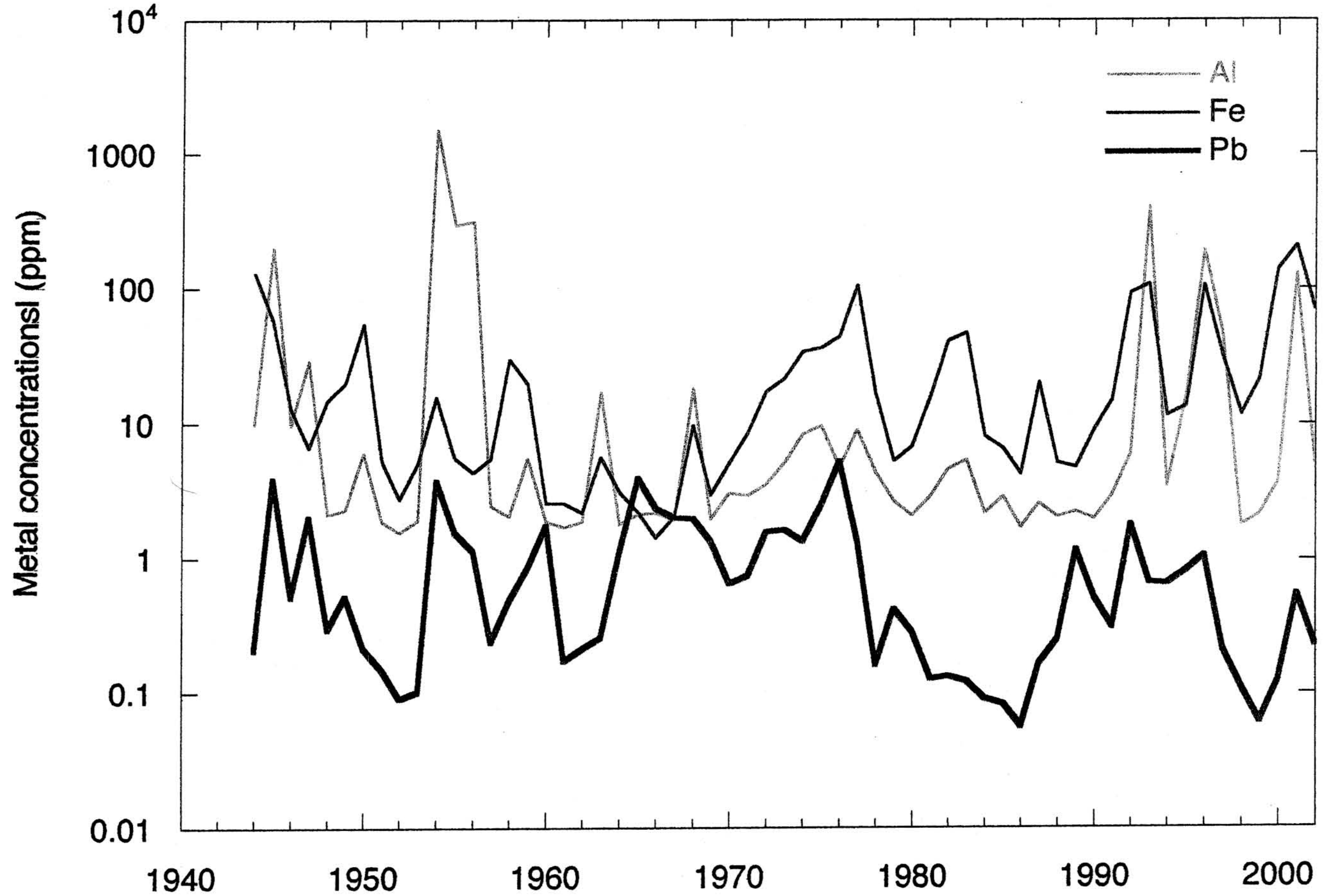

Figure 13. Annual averaged concentrations of total lead, aluminum and iron in bulk skeleton.

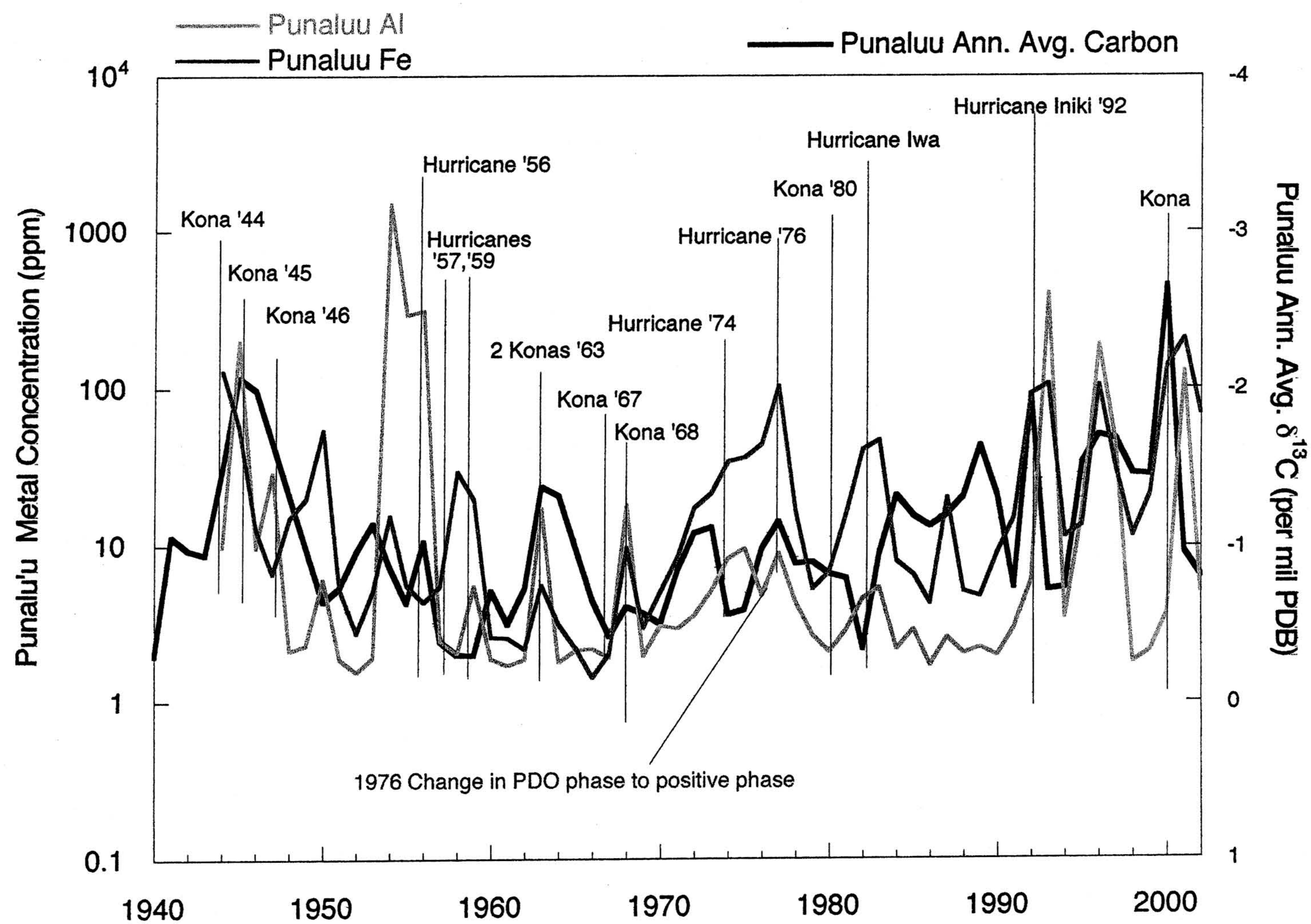

Figure 14. Punalu'u annual averaged metals vs. $\delta^{13}C$ with known storm events.

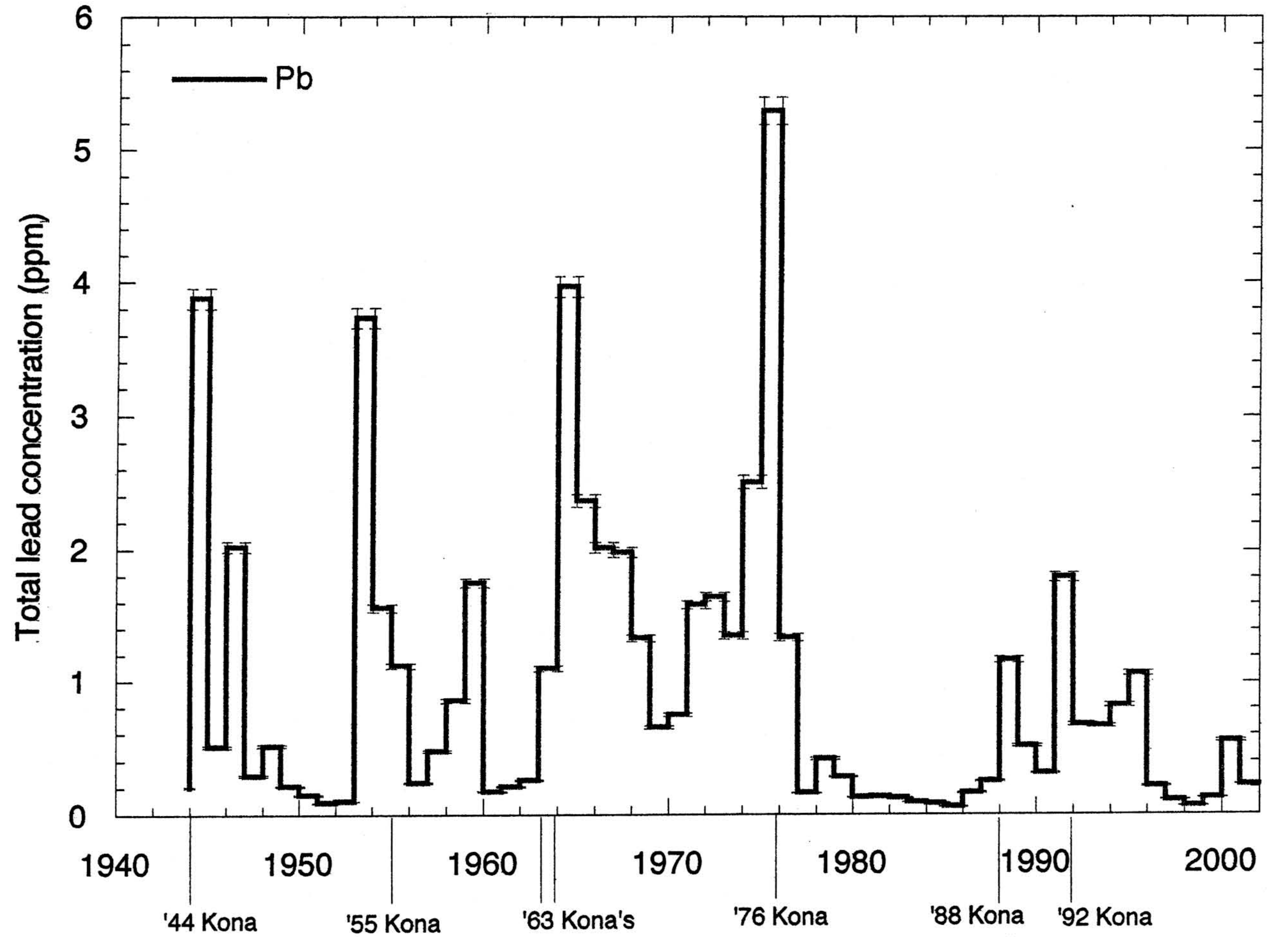

Figure 15. Punalu'u total lead concentration in solid coral. The total lead concentrations were determined by a weighted average of lead isotopes Pb-206, Pb-207, and Pb-208.

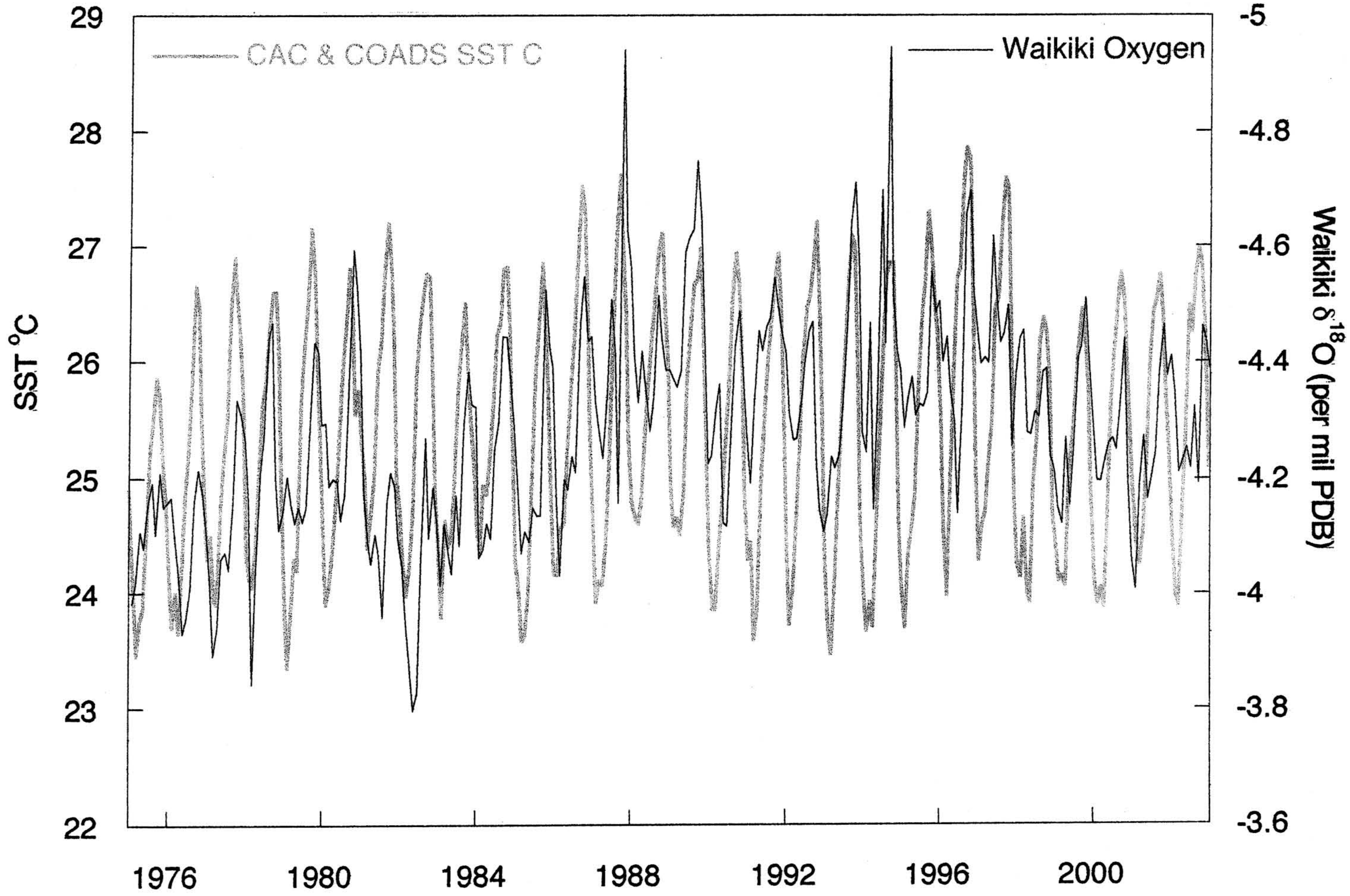

Figure 16. Waikiki $\delta^{18}O$ vs. SST °C

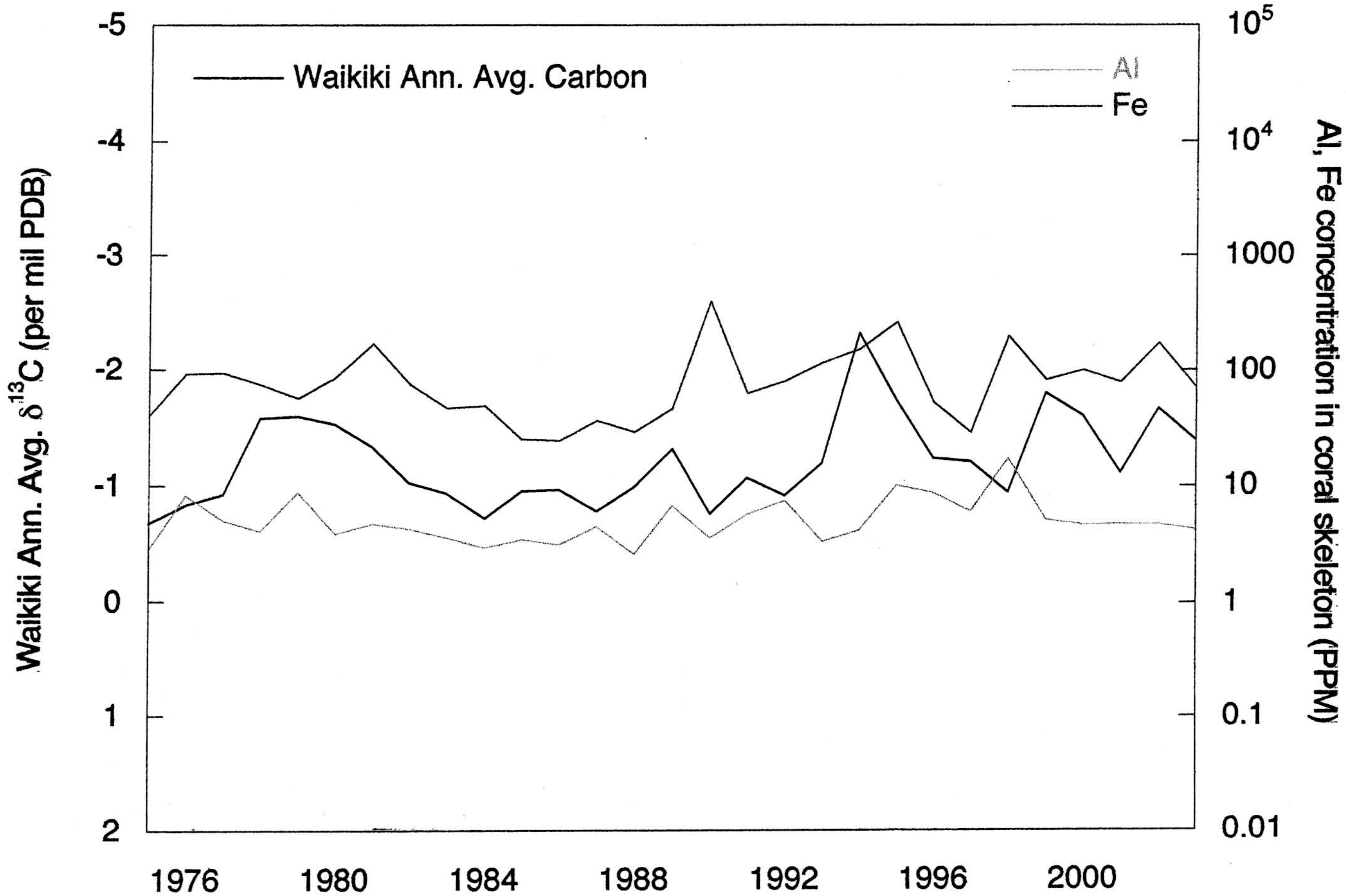

Figure 17. Waikiki annual averaged Fe, Al vs. $\delta^{13}C$

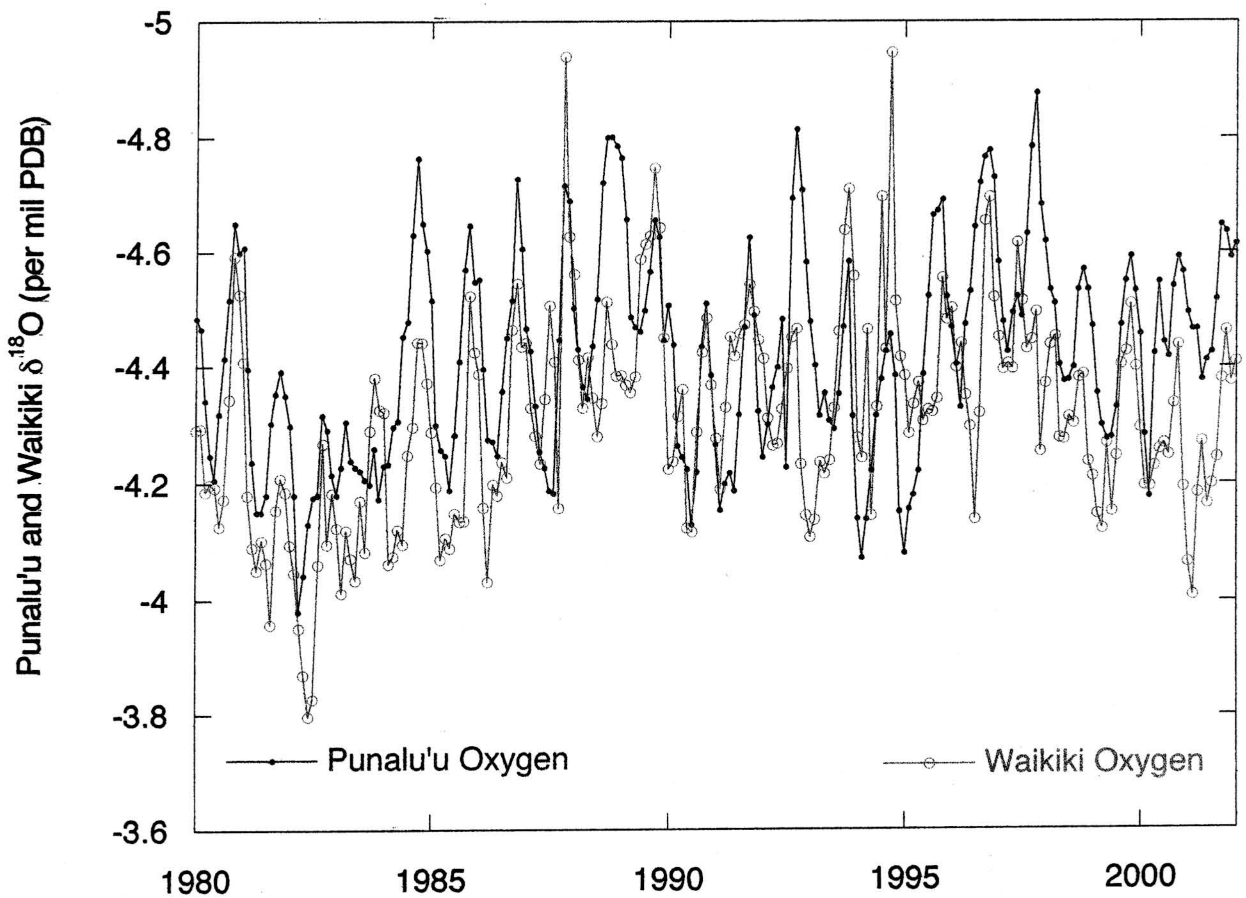

Figure 18. $\delta^{18}O$ time series from Oahu, Hawaii. (A) Punalu'u coral blue line with solid dots, and (B) Waikiki coral orange line with circles.

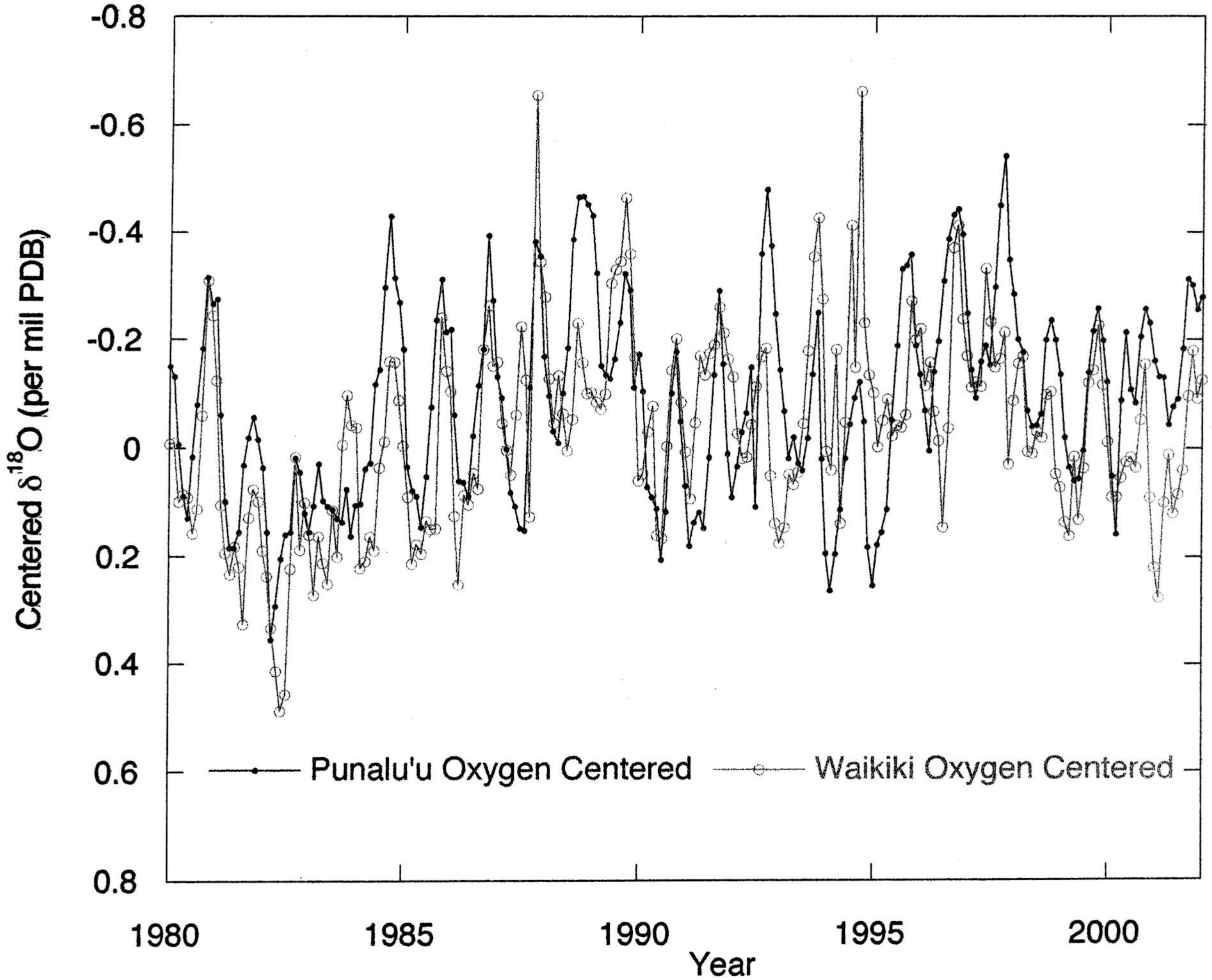

Figure 19. Oahu coral data centered on zero by subtracting each coral's $\delta^{18}O$ average from its time series value

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APPENDIX 1: STABLE ISOTOPIC DATA

Sample	Depth (mm)	δ13C per mil.	δ18O per mil.	Analysis date	Rep. δ13C	Rep. δ18O	Rep. δ13C	Rep. δ18O	Rep. δ13C diff.	Rep. δ18O diff.
HH2-1	1	-0.921	-4.281	1/12/03						
HH2-2	2	-0.735	-4.305	1/12/03						
HH2-3	3	-0.987	-4.273	1/12/03	-0.885	-4.246	-1.089	-4.3	0.204	0.054
HH2-4	4	-0.792	-4.353	1/12/03						
HH2-5	5	-0.373	-4.499	1/12/03						
HH2-6	6	0.291	-4.347	1/12/03						
HH2-7	7	0.031	-4.255	1/12/03						
HH2-8	8	-0.793	-4.232	1/12/03						
HH2-9	9	-1.176	-4.355	1/12/03						
HH2-10	10	-1.591	-4.490	1/12/03						
HH2-11	11	-1.726	-4.510	1/12/03	-1.757	-4.5	-1.694	-4.52	0.063	0.02
HH2-12	12	-1.544	-4.637	1/12/03						
HH2-13	13	-0.936	-4.580	1/12/03						
HH2-14	14	-0.586	-4.522	1/12/03						
HH2-15	15	-0.637	-4.618	1/12/03						
HH2-16	16	-0.659	-4.651	1/12/03						
HH2-17	17	-0.734	-4.635	1/12/03						
HH2-18	18	-0.656	-4.650	1/12/03						
HH2-19	19	-0.790	-4.429	1/12/03	-0.68	-4.438	-0.899	-4.419	0.219	0.019
HH2-20	20	-0.899	-4.419	1/12/03						
HH2-21	21	-1.192	-4.378	1/12/03						
HH2-22	22	-1.188	-4.487	1/12/03						
HH2-23	23	-1.543	-4.452	1/12/03						
HH2-24	24	-2.209	-4.559	1/12/03						
HH2-25	25	-3.035	-4.591	1/12/03						
HH2-26	26	-3.569	-4.590	1/12/03						
HH2-27	27	-4.354	-4.338	1/12/03	-4.1	-4.137	-4.608	-4.538	0.508	0.401
HH2-28	28	-4.196	-4.537	1/12/03						
HH2-29	29	-3.930	-4.380	1/12/03						
HH2-30	30	-2.295	-4.590	1/12/03						
HH2-31	31	-1.092	-4.423	1/13/03						
HH2-32	32	-1.079	-4.158	1/13/03						
HH2-33	33	-1.977	-4.258	1/13/03	-1.977	-4.228	-1.976	-4.288	0.001	0.06
HH2-34	34	-2.566	-4.323	1/13/03						
HH2-35	35	-2.703	-4.546	1/13/03						
HH2-36	36	-1.853	-4.529	1/13/03						
HH2-37	37	-0.805	-4.592	1/13/03						
HH2-38	38	-0.693	-4.522	1/13/03						
HH2-39	39	-1.059	-4.282	1/13/03						
HH2-40	40	-1.622	-4.276	1/13/03						
HH2-41	41	-1.793	-4.316	1/13/03	-1.756	-4.303	-1.83	-4.328	0.074	0.025
HH2-42	42	-2.309	-4.510	1/13/03						
HH2-43	43	-1.749	-4.570	1/13/03						
HH2-44	44	-0.840	-4.534	1/13/03						
HH2-45	45	-0.567	-4.399	1/13/03						
HH2-46	46	-0.719	-4.377	1/13/03						
HH2-47	47	-1.255	-4.375	1/13/03						
HH2-48	48	-1.514	-4.404	1/13/03						
HH2-49	49	-1.722	-4.511	1/13/03	-1.738	-4.634	-1.705	-4.387	0.033	0.247
HH2-50	50	-1.910	-4.535	1/13/03						
HH2-51	51	-2.236	-4.619	1/13/03						
HH2-52	52	-2.320	-4.683	1/13/03						
HH2-53	53	-1.933	-4.877	1/13/03						
HH2-54	54	-1.094	-4.809	1/13/03						
HH2-55	55	-0.854	-4.728	1/13/03						
HH2-56	56	-0.933	-4.567	1/13/03						
HH2-57	57	-1.058	-4.480	1/13/03	-1.075	-4.452	-1.04	-4.507	0.035	0.055
HH2-58	58	-1.153	-4.532	1/13/03						
HH2-59	59	-1.406	-4.488	1/13/03						
HH2-60	60	-1.660	-4.501	1/13/03						
HH2-61	61	-1.987	-4.408	1/14/03						
HH2-62	62	-2.601	-4.472	1/14/03						
HH2-63	63	-3.106	-4.538	1/14/03	-3.059	-4.455	-3.153	-4.621	0.094	0.166
HH2-64	64	-3.270	-4.651	1/14/03						
HH2-65	65	-3.050	-4.764	1/14/03						
HH2-66	66	-2.575	-4.778	1/14/03						
HH2-67	67	-2.062	-4.773	1/14/03						
HH2-68	68	-1.761	-4.741	1/14/03						
HH2-69	69	-1.363	-4.692	1/14/03						
HH2-70	70	-0.926	-4.611	1/14/03						
HH2-71	71	-0.788	-4.512	1/14/03	-0.787	-4.535	-0.789	-4.488	0.002	0.047
HH2-72	72	-0.662	-4.475	1/14/03						
HH2-73	73	-0.684	-4.328	1/14/03						
HH2-74	74	-1.003	-4.341	1/14/03						
HH2-75	75	-1.614	-4.499	1/14/03						
HH2-76	76	-1.926	-4.451	1/14/03						
HH2-77	77	-2.509	-4.541	1/14/03						
HH2-78	78	-2.913	-4.692	1/29/03						
HH2-79	79	-2.696	-4.671	1/14/03	-2.693	-4.677	-2.698	-4.665	0.005	0.012
HH2-80	80	-2.241	-4.664	1/14/03						
HH2-81	81	-1.162	-4.482	1/14/03						
HH2-82	82	-0.689	-4.345	1/14/03						
HH2-83	83	-0.244	-4.147	1/14/03						
HH2-84	84	-0.124	-4.210	1/14/03						
HH2-85	85	-0.395	-4.096	1/14/03						
HH2-86	86	-0.854	-4.060	1/14/03						
HH2-87	87	-1.626	-4.361	1/14/03	-1.681	-4.366	-1.57	-4.356	0.111	0.01
HH2-88	88	-1.859	-4.462	1/14/03						

HH2-89	89	-0.722	-4.417	1/14/03						
HH2-90	90	-0.125	-4.327	1/14/03						
HH2-91	91	-0.144	-4.184	1/15/03						
HH2-92	92	-0.329	-4.069	1/15/03						
HH2-93	93	-0.635	-4.173	1/15/03						
HH2-94	94	-0.948	-4.584	1/30/03						
HH2-95	95	-0.076	-4.447	1/15/03						
HH2-96	96	-0.067	-4.306	1/15/03						
HH2-97	97	-0.409	-4.281	1/15/03						
HH2-98	98	-0.590	-4.362	1/15/03						
HH2-99	99	-1.192	-4.316	1/15/03						
HH2-100	100	-2.315	-4.422	1/15/03						
HH2-101	101	-2.989	-4.510	1/15/03	-3.022	-4.422	-2.956	-4.598	0.066	0.176
HH2-102	102	-2.960	-4.660	1/15/03						
HH2-103	103	-2.864	-4.816	1/15/03						
HH2-104	104	-2.633	-4.806	1/30/03						
HH2-105	105	-2.368	-4.590	1/15/03						
HH2-106	106	-1.783	-4.149	2/5/03						
HH2-107	107	-1.334	-4.496	1/15/03						
HH2-108	108	-1.029	-4.388	1/15/03						
HH2-109	109	-0.868	-4.416	1/15/03	-0.867	-4.397	-0.869	-4.434	0.002	0.037
HH2-110	110	-0.681	-4.345	1/15/03						
HH2-111	111	-0.708	-4.303	1/15/03						
HH2-112	112	-1.059	-4.223	1/15/03						
HH2-113	113	-1.685	-4.293	1/15/03						
HH2-114	114	-1.915	-4.343	1/15/03						
HH2-115	115	-2.091	-4.502	1/15/03						
HH2-116	116	-1.441	-4.652	1/15/03						
HH2-117	117	0.031	-4.413	1/15/03	0.008	-4.4	0.054	-4.426	0.046	0.026
HH2-118	118	0.301	-4.185	1/15/03						
HH2-119	119	-0.228	-4.230	1/15/03						
HH2-120	120	-0.565	-4.149	2/5/03						
HH2-121	121	-0.943	-4.318	1/15/03						
HH2-122	122	-1.767	-4.511	1/15/03						
HH2-123	123	-1.120	-4.510	1/15/03	-1.192	-4.496	-1.047	-4.524	0.145	0.028
HH2-124	124	0.528	-4.316	1/15/03						
HH2-125	125	0.233	-4.190	1/15/03						
HH2-126	126	-0.374	-4.119	1/15/03						
HH2-127	127	-1.293	-4.191	1/15/03						
HH2-128	128	-2.240	-4.253	1/15/03						
HH2-129	129	-2.300	-4.245	1/15/03						
HH2-130	130	-2.011	-4.232	1/15/03						
HH2-131	131	-2.379	-4.335	1/15/03	-2.382	-4.326	-2.375	-4.343	0.007	0.017
HH2-132	132	-2.415	-4.484	1/15/03						
HH2-133	133	-2.220	-4.516	1/15/03						
HH2-134	134	-2.298	-4.400	1/15/03						
HH2-135	135	-2.166	-4.498	1/15/03						
HH2-136	136	-1.425	-4.649	1/15/03						
HH2-137	137	-1.181	-4.674	1/15/03						
HH2-138	138	-1.050	-4.578	1/15/03						
HH2-139	139	-0.880	-4.535	1/15/03	-0.883	-4.542	-0.877	-4.527	0.006	0.015
HH2-140	140	-1.176	-4.441	1/15/03						
HH2-141	141	-1.618	-4.484	1/15/03						
HH2-142	142	-1.555	-4.459	1/15/03						
HH2-143	143	-2.193	-4.499	1/15/03						
HH2-144	144	-2.225	-4.700	1/15/03						
HH2-145	145	-2.180	-4.773	1/15/03						
HH2-146	146	-1.975	-4.786	1/15/03						
HH2-147	147	-1.671	-4.801	1/15/03	-1.667	-4.791	-1.674	-4.81	0.007	0.019
HH2-148	148	-1.451	-4.802	1/15/03						
HH2-149	149	-1.052	-4.791	1/15/03						
HH2-150	150	-0.831	-4.537	1/15/03						
HH2-151	151	-0.587	-4.487	1/16/03						
HH2-152	152	-0.591	-4.376	1/16/03						
HH2-153	153	-0.848	-4.319	1/16/03	-0.826	-4.27	-0.87	-4.367	0.044	0.097
HH2-154	154	-1.385	-4.392	1/16/03						
HH2-155	155	-1.814	-4.445	1/16/03						
HH2-156	156	-1.814	-4.516	1/16/03						
HH2-157	157	-1.728	-4.707	1/16/03						
HH2-158	158	-1.101	-4.716	1/16/03						
HH2-159	159	-0.549	-4.416	1/16/03						
HH2-160	160	-0.809	-4.125	1/16/03						
HH2-161	161	-1.038	-4.214	1/16/03	-0.995	-4.177	-1.081	-4.25	0.086	0.073
HH2-162	162	-1.072	-4.236	1/16/03						
HH2-163	163	-1.328	-4.272	1/16/03						
HH2-164	164	-1.324	-4.424	1/16/03						
HH2-165	165	-1.693	-4.435	1/16/03						
HH2-166	166	-1.653	-4.592	1/16/03						
HH2-167	167	-1.737	-4.728	1/16/03						
HH2-168	168	-1.051	-4.522	1/16/03						
HH2-169	169	-0.738	-4.461	1/16/03	-0.73	-4.408	-0.745	-4.514	0.015	0.106
HH2-170	170	-0.688	-4.407	1/16/03						
HH2-171	171	-0.489	-4.243	1/16/03						
HH2-172	172	-0.847	-4.253	1/16/03						
HH2-173	173	-1.073	-4.291	1/16/03						
HH2-174	174	-1.148	-4.264	1/16/03						
HH2-175	175	-1.057	-4.453	1/16/03						
HH2-176	176	-1.264	-4.577	1/16/03						
HH2-177	177	-1.263	-4.544	1/16/03	-1.188	-4.479	-1.337	-4.608	0.149	0.129

HH2-178	178	-1.179	-4.646	1/16/03						
HH2-179	179	-1.088	-4.603	1/16/03						
HH2-180	180	-0.957	-4.437	1/16/03						
HH2-181	181	-0.942	-4.368	1/24/03						
HH2-182	182	-1.045	-4.227	1/24/03						
HH2-183	183	-1.148	-4.180	1/24/03	-1.154	-4.182	-1.141	-4.178	0.013	0.004
HH2-184	184	-1.220	-4.247	1/24/03						
HH2-185	185	-1.403	-4.268	1/24/03						
HH2-186	186	-1.361	-4.215	1/24/03						
HH2-187	187	-1.650	-4.426	1/24/03						
HH2-188	188	-2.029	-4.575	1/24/03						
HH2-189	189	-2.117	-4.609	1/24/03						
HH2-190	190	-1.870	-4.648	1/24/03						
HH2-191	191	-1.682	-4.784	1/24/03	-1.709	-4.774	-1.654	-4.793	0.055	0.019
HH2-192	192	-1.484	-4.701	1/24/03						
HH2-193	193	-1.021	-4.593	1/24/03						
HH2-194	194	-0.895	-4.483	1/24/03						
HH2-195	195	-0.805	-4.425	1/24/03						
HH2-196	196	-0.779	-4.480	1/24/03						
HH2-197	197	-0.833	-4.290	1/24/03						
HH2-198	198	-1.050	-4.310	1/24/03						
HH2-199	199	-0.962	-4.271	1/24/03	-0.951	-4.283	-0.972	-4.259	0.021	0.024
HH2-200	200	-1.042	-4.220	1/24/03						
HH2-201	201	-1.050	-4.258	1/24/03						
HH2-202	202	-1.063	-4.090	1/24/03						
HH2-203	203	-1.129	-4.233	1/24/03						
HH2-204	204	-0.841	-4.260	1/24/03						
HH2-205	205	-0.861	-4.186	1/24/03						
HH2-206	206	-0.898	-4.216	1/24/03						
HH2-207	207	-0.672	-4.228	1/24/03	-0.633	-4.216	-0.711	-4.239	0.078	0.023
HH2-208	208	-0.750	-4.226	1/24/03						
HH2-209	209	-1.164	-4.307	1/24/03						
HH2-210	210	-1.296	-4.211	1/24/03						
HH2-211	211	-1.416	-4.163	1/24/03						
HH2-212	212	-0.886	-4.270	1/24/03						
HH2-213	213	-0.590	-4.339	1/24/03	-0.61	-4.27	-0.57	-4.408	0.04	0.138
HH2-214	214	0.069	-4.161	1/24/03						
HH2-215	215	0.370	-4.183	1/24/03						
HH2-216	216	0.110	-4.058	1/24/03						
HH2-217	217	0.125	-3.975	1/24/03						
HH2-218	218	-0.518	-4.264	1/24/03						
HH2-219	219	-0.539	-4.337	1/24/03						
HH2-220	220	-0.477	-4.392	1/24/03						
HH2-221	221	-0.414	-4.354	1/24/03	-0.429	-4.355	-0.399	-4.352	0.03	0.003
HH2-222	222	-0.504	-4.303	1/24/03						
HH2-223	223	-0.516	-4.180	1/24/03						
HH2-224	224	-1.092	-4.150	1/24/03						
HH2-225	225	-1.210	-4.151	1/24/03						
HH2-226	226	-1.254	-4.237	1/24/03						
HH2-227	227	-1.441	-4.396	1/24/03						
HH2-228	228	-1.628	-4.608	1/24/03						
HH2-229	229	-1.273	-4.599	1/24/03	-1.248	-4.638	-1.297	-4.559	0.049	0.079
HH2-230	230	-0.646	-4.649	1/24/03						
HH2-231	231	-0.295	-4.517	1/24/03						
HH2-232	232	-0.276	-4.415	1/24/03						
HH2-233	233	-0.430	-4.319	1/24/03						
HH2-234	234	-0.489	-4.206	1/24/03						
HH2-235	235	-0.611	-4.247	1/24/03						
HH2-236	236	-1.063	-4.341	1/24/03						
HH2-237	237	-1.510	-4.466	1/24/03						
HH2-238	238	-1.504	-4.484	1/24/03						
HH2-239	239	-1.189	-4.549	1/24/03						
HH2-240	240	-0.995	-4.597	1/24/03						
HH2-241	241	-0.607	-4.490	1/26/03						
HH2-242	242	-0.497	-4.467	1/26/03						
HH2-243	243	-0.556	-4.437	1/26/03	-0.581	-4.44	-0.53	-4.433	0.051	0.007
HH2-244	244	-0.446	-4.314	1/26/03						
HH2-245	245	-0.472	-4.258	1/26/03						
HH2-246	246	-0.843	-4.236	1/26/03						
HH2-247	247	-1.172	-4.250	1/26/03						
HH2-248	248	-1.182	-4.303	1/26/03						
HH2-249	249	-1.249	-4.303	1/26/03						
HH2-250	250	-1.393	-4.404	1/26/03						
HH2-251	251	-1.464	-4.619	1/26/03	-1.492	-4.581	-1.435	-4.657	0.057	0.076
HH2-252	252	-1.266	-4.694	1/26/03						
HH2-253	253	-0.699	-4.756	1/26/03						
HH2-254	254	-0.361	-4.561	1/26/03						
HH2-255	255	-0.456	-4.460	1/26/03						
HH2-256	256	-0.527	-4.404	1/26/03						
HH2-257	257	-0.395	-4.346	1/26/03						
HH2-258	258	-0.671	-4.335	1/26/03						
HH2-259	259	-0.906	-4.187	1/26/03	-0.877	-4.192	-0.935	-4.182	0.058	0.01
HH2-260	260	-1.105	-4.143	1/26/03						
HH2-261	261	-1.528	-4.340	1/26/03						
HH2-262	262	-1.751	-4.404	1/26/03						
HH2-263	263	-1.463	-4.547	1/26/03						
HH2-264	264	-1.267	-4.573	1/26/03						
HH2-265	265	-1.210	-4.509	1/26/03						
HH2-266	266	-0.747	-4.404	1/26/03						

HH2-267	267	-0.659	-4.433	1/26/03	-0.673	-4.433	-0.644	-4.433	0.029	0
HH2-268	268	-0.662	-4.389	1/26/03						
HH2-269	269	-0.711	-4.379	1/26/03						
HH2-270	270	-0.900	-4.336	1/26/03						
HH2-271	271	-1.077	-4.270	1/28/03						
HH2-272	272	-1.039	-4.208	1/28/03						
HH2-273	273	-1.180	-4.212	1/28/03	-1.177	-4.199	-1.183	-4.224	0.006	0.025
HH2-274	274	-1.208	-4.234	1/28/03						
HH2-275	275	-1.251	-4.289	1/28/03						
HH2-276	276	-1.392	-4.230	1/28/03						
HH2-277	277	-1.281	-4.144	1/28/03						
HH2-278	278	-1.452	-4.226	1/28/03						
HH2-279	279	-1.298	-4.186	1/28/03						
HH2-280	280	-1.390	-4.156	1/28/03						
HH2-281	281	-1.276	-4.428	1/28/03	-1.376	-4.428	-1.175	-4.428	0.201	0
HH2-282	282	-0.939	-4.474	1/28/03						
HH2-283	283	-0.468	-4.353	1/28/03						
HH2-284	284	-0.593	-4.240	1/28/03						
HH2-285	285	-0.850	-4.273	1/28/03						
HH2-286	286	-1.034	-4.250	1/28/03						
HH2-287	287	-1.083	-4.172	1/28/03						
HH2-288	288	-1.521	-4.282	1/28/03						
HH2-289	289	-1.345	-4.538	1/28/03	-1.304	-4.535	-1.385	-4.54	0.081	0.005
HH2-290	290	-0.964	-4.578	1/28/03						
HH2-291	291	0.052	-4.458	1/28/03						
HH2-292	292	0.316	-4.265	1/28/03						
HH2-293	293	-0.301	-4.276	1/28/03						
HH2-294	294	-0.639	-4.201	1/28/03						
HH2-295	295	-0.644	-4.251	1/28/03						
HH2-296	296	-0.736	-4.331	1/28/03						
HH2-297	297	-0.875	-4.450	1/28/03	-0.852	-4.411	-0.898	-4.488	0.046	0.077
HH2-298	298	-0.293	-4.501	1/28/03						
HH2-299	299	0.785	-4.160	1/28/03						
HH2-300	300	-0.077	-4.215	1/28/03						
HH2-301	301	-0.616	-3.928	1/29/03						
HH2-302	302	-1.365	-4.053	1/29/03						
HH2-303	303	-0.990	-4.056	1/29/03	-1.047	-4.053	-0.932	-4.058	0.115	0.005
HH2-304	304	-1.075	-4.204	1/29/03						
HH2-305	305	-1.130	-4.248	1/29/03						
HH2-306	306	-1.019	-4.331	1/29/03						
HH2-307	307	-0.795	-4.345	1/29/03						
HH2-308	308	-0.438	-4.337	1/29/03						
HH2-309	309	-0.479	-4.304	1/29/03						
HH2-310	310	-0.525	-4.225	1/29/03						
HH2-311	311	-0.574	-4.181	1/29/03	-0.534	-4.175	-0.613	-4.187	0.079	0.012
HH2-312	312	-1.041	-4.225	1/29/03						
HH2-313	313	-1.269	-4.182	1/29/03						
HH2-314	314	-1.485	-4.164	2/5/03						
HH2-315	315	-1.819	-4.281	1/29/03						
HH2-316	316	-1.846	-4.315	1/29/03						
HH2-317	317	-1.985	-4.324	1/29/03						
HH2-318	318	-1.734	-4.402	1/29/03						
HH2-319	319	-1.797	-4.561	1/29/03	-1.784	-4.571	-1.81	-4.551	0.026	0.02
HH2-320	320	-1.890	-4.619	1/29/03						
HH2-321	321	-1.591	-4.677	1/29/03						
HH2-322	322	-1.245	-4.732	1/29/03						
HH2-323	323	-1.010	-4.619	1/29/03						
HH2-324	324	-0.784	-4.520	1/29/03						
HH2-325	325	-0.787	-4.425	2/5/03						
HH2-326	326	-0.659	-4.500	1/29/03						
HH2-327	327	-0.893	-4.441	1/29/03	-0.888	-4.43	-0.897	-4.451	0.009	0.021
HH2-328	328	-0.934	-4.360	1/29/03						
HH2-329	329	-0.981	-4.332	1/29/03						
HH2-330	330	-1.075	-4.318	1/29/03						
HH2-331	331	-1.117	-4.228	1/30/03						
HH2-332	332	-1.401	-4.448	1/30/03						
HH2-333	333	-1.456	-4.416	1/30/03	-1.474	-4.43	-1.437	-4.401	0.037	0.029
HH2-334	334	-0.592	-4.325	1/30/03						
HH2-335	335	-0.037	-4.189	1/30/03						
HH2-336	336	-0.205	-4.046	1/30/03						
HH2-337	337	-0.413	-3.978	1/30/03						
HH2-338	338	-0.830	-4.123	1/30/03						
HH2-339	339	-1.095	-4.104	1/30/03						
HH2-340	340	-1.161	-4.103	1/30/03						
HH2-341	341	-1.076	-4.183	1/30/03	-1.123	-4.165	-1.029	-4.201	0.094	0.036
HH2-342	342	-0.770	-4.426	1/30/03						
HH2-343	343	-0.008	-4.333	1/30/03						
HH2-344	344	0.317	-4.196	1/30/03						
HH2-345	345	0.031	-4.125	1/30/03						
HH2-346	346	-0.475	-4.012	1/30/03						
HH2-347	347	-1.088	-4.188	1/30/03						
HH2-348	348	-1.427	-4.372	1/30/03						
HH2-349	349	-1.281	-4.401	1/30/03	-1.287	-4.37	-1.275	-4.431	0.012	0.061
HH2-350	350	-0.515	-4.408	1/30/03						
HH2-351	351	0.001	-4.395	1/30/03						
HH2-352	352	0.051	-4.277	1/30/03						
HH2-353	353	-0.123	-4.171	1/30/03						
HH2-354	354	-0.536	-4.128	1/30/03						
HH2-355	355	-0.567	-4.168	1/30/03						

HH2-356	356	-0.922	-4.158	1/30/03						
HH2-357	357	-1.472	-4.421	1/30/03	-1.444	-4.38	-1.499	-4.462	0.055	0.082
HH2-358	358	-1.318	-4.478	1/30/03						
HH2-359	359	-0.790	-4.521	1/30/03						
HH2-360	360	0.228	-4.266	1/30/03						
HH2-361	361	0.120	-4.270	1/31/03						
HH2-362	362	-0.406	-4.249	1/31/03						
HH2-363	363	-0.555	-4.135	1/31/03	-0.538	-4.18	-0.572	-4.09	0.034	0.09
HH2-364	364	-0.641	-4.279	1/31/03						
HH2-365	365	-0.910	-4.383	1/31/03						
HH2-366	366	-0.939	-4.440	1/31/03						
HH2-367	367	-0.110	-4.338	1/31/03						
HH2-368	368	-0.076	-4.402	1/31/03						
HH2-369	369	0.224	-4.442	1/31/03						
HH2-370	370	0.103	-4.291	1/31/03						
HH2-371	371	-0.331	-4.213	1/31/03	-0.439	-4.227	-0.223	-4.198	0.216	0.029
HH2-372	372	-0.804	-4.223	1/31/03						
HH2-373	373	-1.095	-4.431	1/31/03						
HH2-374	374	-1.352	-4.801	1/31/03						
HH2-375	375	-0.794	-4.809	1/31/03						
HH2-376	376	-0.128	-4.677	1/31/03						
HH2-377	377	0.040	-4.508	1/31/03						
HH2-378	378	-0.213	-4.458	1/31/03						
HH2-379	379	-0.653	-4.434	1/31/03	-0.641	-4.421	-0.664	-4.447	0.023	0.026
HH2-380	380	-0.996	-4.480	1/31/03						
HH2-381	381	-0.800	-4.346	1/31/03						
HH2-382	382	-1.443	-4.691	1/31/03						
HH2-383	383	-0.984	-4.760	1/31/03						
HH2-384	384	-0.638	-4.836	1/31/03						
HH2-385	385	-0.528	-4.647	1/31/03						
HH2-386	386	-0.228	-4.565	1/31/03						
HH2-387	387	-0.471	-4.438	1/31/03	-0.487	-4.495	-0.454	-4.38	0.033	0.115
HH2-388	388	-0.742	-4.428	1/31/03						
HH2-389	389	-1.123	-4.416	1/31/03						
HH2-390	390	-1.419	-4.354	1/31/03						
HH2-391	391	-1.568	-4.275	2/5/03						
HH2-392	392	-1.412	-4.424	2/5/03						
HH2-393	393	-1.513	-4.576	2/5/03	-1.521	-4.57	-1.505	-4.582	0.016	0.012
HH2-394	394	-0.824	-4.599	2/5/03						
HH2-395	395	-0.598	-4.614	2/5/03						
HH2-396	396	-0.458	-4.470	2/5/03						
HH2-397	397	-0.392	-4.430	2/5/03						
HH2-398	398	-0.583	-4.303	2/5/03						
HH2-399	399	-0.932	-4.183	2/5/03						
HH2-400	400	-1.168	-4.143	2/5/03						
HH2-401	401	-1.621	-4.162	2/5/03	-1.598	-4.181	-1.644	-4.143	0.046	0.038
HH2-402	402	-2.123	-4.197	2/5/03						
HH2-403	403	-2.455	-4.259	2/5/03						
HH2-404	404	-2.521	-4.323	2/5/03						
HH2-405	405	-2.505	-4.269	2/5/03						
HH2-406	406	-2.460	-4.258	2/5/03						
HH2-407	407	-2.415	-4.406	2/5/03						
HH2-408	408	-2.264	-4.350	2/5/03						
HH2-409	409	-2.046	-4.396	2/5/03	-2.045	-4.375	-2.046	-4.417	0.001	0.042
HH2-410	410	-1.835	-4.289	2/5/03						
HH2-411	411	-1.335	-4.372	2/5/03						
HH2-412	412	-1.044	-4.329	2/5/03						
HH2-413	413	-0.578	-4.320	2/5/03						
HH2-414	414	-0.574	-4.269	2/5/03						
HH2-415	415	-0.607	-4.135	2/5/03						
HH2-416	416	-0.529	-4.109	2/5/03						
HH2-417	417	-0.528	-4.114	2/5/03	-0.556	-4.156	-0.5	-4.072	0.056	0.084
HH2-418	418	-0.759	-4.135	2/5/03						
HH2-419	419	-1.040	-4.040	2/5/03						
HH2-420	420	-1.238	-4.106	2/5/03						
HH2-421	421	-1.435	-4.047	2/5/03						
HH2-422	422	-1.492	-4.199	2/5/03						
HH2-423	423	-1.264	-4.181	2/5/03	-1.151	-4.172	-1.376	-4.19	0.225	0.018
HH2-424	424	-0.657	-4.190	2/5/03						
HH2-425	425	-0.501	-4.087	2/5/03						
HH2-426	426	-0.254	-4.047	2/5/03						
HH2-427	427	-0.303	-4.100	2/5/03						
HH2-428	428	-0.171	-4.148	2/5/03						
HH2-429	429	-0.179	-3.993	2/5/03						
HH2-430	430	-0.429	-4.063	2/13/03						
HH2-431	431	-0.368	-4.266	2/5/03						
HH2-432	432	-0.120	-4.267	2/5/03						
HH2-433	433	0.237	-4.315	2/5/03	0.193	-4.309	0.281	-4.321	0.088	0.012
HH2-434	434	0.269	-4.118	2/5/03						
HH2-435	435	-0.583	-4.110	2/5/03						
HH2-436	436	-0.834	-4.146	2/5/03						
HH2-437	437	-1.343	-4.254	2/5/03						
HH2-438	438	-1.538	-4.312	2/5/03						
HH2-439	439	-0.956	-4.468	2/5/03						
HH2-440	440	-0.521	-4.538	2/5/03						
HH2-441	441	0.352	-4.377	2/5/03	0.325	-4.377	0.378	-4.377	0.053	0
HH2-442	442	-1.340	-4.120	2/5/03						
HH2-443	443	-0.195	-4.321	2/5/03						
HH2-444	444	-0.668	-4.242	2/5/03						

HH2-445	445	-0.690	-4.269	2/5/03						
HH2-446	446	-0.792	-4.404	2/5/03						
HH2-447	447	-0.807	-4.287	2/5/03	-0.801	-4.245	-0.813	-4.329	0.012	0.084
HH2-448	448	-1.201	-4.467	2/5/03						
HH2-449	449	-0.471	-4.560	2/5/03						
HH2-450	450	0.936	-4.484	2/5/03	0.936	-4.484	0.378	-4.377	0.558	0.107
HH2-451	451	0.657	-4.277	2/11/03						
HH2-452	452	0.093	-4.264	2/11/03						
HH2-453	453	-0.637	-4.306	2/11/03	-0.63	-4.319	-0.643	-4.293	0.013	0.026
HH2-454	454	-1.204	-4.439	2/11/03						
HH2-455	455	-1.220	-4.553	2/11/03						
HH2-456	456	-0.848	-4.646	2/11/03						
HH2-457	457	-0.094	-4.709	2/11/03						
HH2-458	458	0.526	-4.420	2/11/03						
HH2-459	459	0.233	-4.348	2/11/03						
HH2-460	460	-0.280	-4.189	2/11/03						
HH2-461	461	-0.468	-4.167	2/11/03	-0.484	-4.189	-0.452	-4.145	0.032	0.044
HH2-462	462	-0.596	-4.167	2/11/03						
HH2-463	463	-1.009	-4.487	2/11/03						
HH2-464	464	-0.645	-4.611	2/11/03						
HH2-465	465	-0.219	-4.523	2/11/03						
HH2-466	466	0.253	-4.423	2/11/03						
HH2-467	467	0.153	-4.184	2/11/03						
HH2-468	468	-0.104	-4.235	2/11/03						
HH2-469	469	-0.372	-4.144	2/11/03	-0.415	-4.182	-0.329	-4.106	0.086	0.076
HH2-470	470	-0.520	-4.194	2/11/03						
HH2-471	471	-0.929	-4.290	2/11/03						
HH2-472	472	-1.442	-4.427	2/11/03						
HH2-473	473	-1.839	-4.531	2/11/03						
HH2-474	474	-1.495	-4.604	2/11/03						
HH2-475	475	-0.646	-4.533	2/11/03						
HH2-476	476	-0.176	-4.462	2/11/03						
HH2-477	477	-0.185	-4.212	2/11/03	-0.186	-4.231	-0.183	-4.192	0.003	0.039
HH2-478	478	-0.487	-4.267	2/11/03						
HH2-479	479	-0.846	-4.221	2/11/03						
HH2-480	480	-1.118	-4.228	2/11/03						
HH2-481	481	-1.501	-4.225	2/12/03						
HH2-482	482	-1.542	-4.143	2/12/03						
HH2-483	483	-1.632	-4.209	2/12/03	-1.647	-4.187	-1.616	-4.231	0.031	0.044
HH2-484	484	-1.511	-4.138	2/12/03						
HH2-485	485	-1.371	-4.349	2/19/03						
HH2-486	486	-0.795	-4.186	2/12/03						
HH2-487	487	0.073	-4.291	2/12/03						
HH2-488	488	0.281	-4.109	2/12/03						
HH2-489	489	-0.016	-4.057	2/12/03						
HH2-490	490	-0.214	-4.063	2/12/03						
HH2-491	491	-0.431	-3.935	2/12/03	-0.448	-4.033	-0.414	-3.837	0.034	0.196
HH2-492	492	-1.130	-4.090	2/12/03						
HH2-493	493	-1.156	-4.080	2/12/03						
HH2-494	494	-1.379	-4.314	2/12/03						
HH2-495	495	-1.325	-4.391	2/12/03						
HH2-496	496	-1.019	-4.281	2/12/03						
HH2-497	497	-0.182	-4.366	2/12/03						
HH2-498	498	0.046	-4.307	2/12/03						
HH2-499	499	-0.096	-4.242	2/12/03	-0.09	-4.244	-0.102	-4.24	0.012	0.004
HH2-500	500	-0.437	-4.231	2/12/03						
HH2-501	501	-0.603	-4.178	2/12/03						
HH2-502	502	-0.943	-4.206	2/12/03						
HH2-503	503	-1.505	-4.319	2/12/03						
HH2-504	504	-1.600	-4.281	2/12/03						
HH2-505	505	-1.459	-4.311	2/12/03						
HH2-506	506	-1.513	-4.360	2/12/03						
HH2-507	507	-1.134	-4.450	2/12/03	-1.119	-4.394	-1.149	-4.505	0.03	0.111
HH2-508	508	-0.616	-4.319	2/12/03						
HH2-509	509	-0.219	-4.270	2/12/03						
HH2-510	510	-0.071	-4.130	2/12/03						
HH2-511	511	-0.610	-3.992	2/13/03						
HH2-512	512	-1.064	-3.920	2/13/03						
HH2-513	513	-1.207	-3.960	2/13/03	-1.254	-3.998	-1.159	-3.921	0.095	0.077
HH2-514	514	-1.744	-3.920	2/13/03						
HH2-515	515	-1.739	-4.136	2/13/03						
HH2-516	516	-1.712	-4.291	2/13/03						
HH2-517	517	-1.594	-4.476	2/13/03						
HH2-518	518	-1.196	-4.546	2/13/03						
HH2-519	519	-0.731	-4.588	2/13/03						
HH2-520	520	-0.664	-4.502	2/13/03						
HH2-521	521	-0.444	-4.384	2/13/03	-0.463	-4.36	-0.424	-4.408	0.039	0.048
HH2-522	522	-0.101	-4.352	2/13/03						
HH2-523	523	-0.244	-4.197	2/13/03						
HH2-524	524	-0.777	-4.169	2/13/03						
HH2-525	525	-0.709	-4.127	2/13/03						
HH2-526	526	-1.031	-4.032	2/13/03						
HH2-527	527	-1.372	-4.143	2/13/03						
HH2-528	528	-1.488	-4.065	2/13/03						
HH2-529	529	-1.485	-4.140	2/13/03	-1.471	-4.183	-1.498	-4.096	0.027	0.087
HH2-530	530	-1.474	-4.230	2/13/03						
HH2-531	531	-1.455	-4.305	2/13/03						
HH2-532	532	-1.257	-4.275	2/13/03						
HH2-533	533	-0.941	-4.357	2/13/03						

HH2-534	534	-0.585	-4.492	2/13/03						
HH2-535	535	-0.272	-4.464	2/13/03						
HH2-536	536	-0.246	-4.388	2/13/03						
HH2-537	537	-0.245	-4.298	2/13/03	-0.245	-4.351	-0.245	-4.245	0	0.106
HH2-538	538	-0.362	-4.287	2/13/03						
HH2-539	539	-0.656	-4.183	2/13/03						
HH2-540	540	-0.865	-4.209	2/13/03						
HH2-541	541	-0.872	-3.950	2/13/03						
HH2-542	542	-0.915	-3.986	2/13/03						
HH2-543	543	-1.075	-4.076	2/13/03	-1.074	-4.039	-1.075	-4.112	0.001	0.073
HH2-544	544	-1.613	-4.203	2/13/03						
HH2-545	545	-0.826	-4.225	2/13/03						
HH2-546	546	-0.302	-4.342	2/13/03						
HH2-547	547	-0.200	-4.170	2/13/03						
HH2-548	548	-0.103	-4.154	2/13/03						
HH2-549	549	-0.287	-4.008	2/13/03						
HH2-550	550	-0.528	-4.073	2/13/03						
HH2-551	551	-0.638	-4.016	2/13/03	-0.621	-4.003	-0.655	-4.029	0.034	0.026
HH2-552	552	-0.931	-3.975	2/13/03						
HH2-553	553	-0.850	-4.139	2/13/03						
HH2-554	554	-1.117	-4.268	2/13/03						
HH2-555	555	-0.934	-4.285	2/13/03						
HH2-556	556	-0.900	-4.396	2/13/03						
HH2-557	557	-0.742	-4.526	2/13/03						
HH2-558	558	-0.464	-4.569	2/13/03						
HH2-559	559	-0.183	-4.441	2/13/03	-0.107	-4.391	-0.259	-4.491	0.152	0.1
HH2-560	560	-0.285	-4.421	2/13/03						
HH2-561	561	-0.209	-4.319	2/13/03						
HH2-562	562	-0.877	-4.355	2/13/03	-0.417	-4.405	-1.336	-4.304	0.919	0.101
HH2-563	563	-1.364	-4.101	2/13/03						
HH2-564	564	-1.414	-4.070	2/13/03						
HH2-565	565	-2.442	-3.973	2/13/03						
HH2-566	566	-2.863	-4.065	2/13/03						
HH2-567	567	-3.337	-4.102	2/13/03	-3.447	-4.193	-3.227	-4.01	0.22	0.183
HH2-568	568	-3.632	-4.229	2/13/03						
HH2-569	569	-3.576	-4.466	2/13/03						
HH2-570	570	-2.900	-4.433	2/13/03						
HH2-571	571	-1.375	-4.223	2/15/03						
HH2-572	572	-0.632	-4.076	2/15/03						
HH2-573	573	-0.692	-4.067	2/15/03	-0.708	-4.093	-0.675	-4.04	0.033	0.053
HH2-574	574	-1.502	-4.131	2/15/03						
HH2-575	575	-2.101	-4.082	2/15/03						
HH2-576	576	-2.707	-4.028	2/15/03						
HH2-577	577	-3.118	-4.053	2/15/03						
HH2-578	578	-3.363	-3.994	2/15/03						
HH2-579	579	-3.171	-4.111	2/15/03						
HH2-580	580	-3.148	-4.138	2/15/03						
HH2-581	581	-2.438	-4.112	2/15/03	-2.513	-4.119	-2.362	-4.104	0.151	0.015
HH2-582	582	-2.118	-4.223	2/15/03						
HH2-583	583	-1.660	-4.198	2/15/03						
HH2-584	584	-0.961	-4.036	2/15/03						
HH2-585	585	-0.735	-3.963	2/15/03						
HH2-586	586	-0.694	-3.965	2/15/03						
HH2-587	587	-0.741	-3.923	2/15/03						
HH2-588	588	-0.949	-3.919	2/15/03						
HH2-589	589	-0.705	-3.863	2/15/03	-0.756	-3.887	-0.653	-3.839	0.103	0.048
HH2-590	590	-0.230	-3.850	2/15/03						
HH2-591	591	-0.479	-3.909	2/15/03						
HH2-592	592	-1.212	-4.175	2/15/03						
HH2-593	593	-2.023	-4.187	2/15/03						
HH2-594	594	-2.373	-4.125	2/15/03						
HH2-595	595	-2.802	-4.283	2/15/03						
HH2-596	596	-2.664	-4.255	2/15/03						
HH2-597	597	-2.843	-4.331	2/15/03	-2.809	-4.331	-2.876	-4.33	0.067	0.001
HH2-598	598	-2.116	-4.354	2/15/03						
HH2-599	599	-1.902	-4.435	2/15/03						
HH2-600	600	-0.841	-4.233	2/15/03						
HH2-601	601	-0.885	-4.149	2/15/03						
HH2-602	602	-0.782	-3.978	2/15/03						
HH2-603	603	-0.791	-3.876	2/15/03	-0.816	-3.878	-0.765	-3.873	0.051	0.005
HH2-604	604	-0.775	-3.896	2/15/03						
HH2-605	605	0.171	-3.809	2/15/03						
HH2-606	606	0.283	-3.833	2/15/03						
HH2-607	607	-0.108	-3.893	2/15/03						
HH2-608	608	-1.617	-4.022	2/15/03						
HH2-609	609	-2.347	-4.076	2/15/03						
HH2-610	610	-2.259	-4.251	2/15/03						
HH2-611	611	-1.289	-4.165	2/15/03	-1.245	-4.155	-1.333	-4.174	0.088	0.019
HH2-612	612	-0.639	-4.246	2/15/03						
HH2-613	613	-0.116	-4.062	2/15/03						
HH2-614	614	-0.304	-3.997	2/15/03						
HH2-615	615	-0.877	-4.124	2/15/03						
HH2-616	616	-2.105	-4.269	2/15/03						
HH2-617	617	-1.558	-4.419	2/15/03						
HH2-618	618	-0.159	-4.265	2/15/03						
HH2-619	619	0.174	-4.211	2/15/03	0.202	-4.214	0.145	-4.207	0.057	0.007
HH2-620	620	-0.765	-4.078	2/15/03						
HH2-621	621	-1.653	-4.142	2/15/03						
HH2-622	622	-2.448	-4.361	2/15/03						

HH2-623	623	-1.626	-4.496	2/15/03						
HH2-624	624	-0.226	-4.289	2/15/03						
HH2-625	625	0.086	-4.099	2/15/03						
HH2-626	626	-0.251	-4.033	2/15/03						
HH2-627	627	-1.179	-4.010	2/15/03	-1.207	-3.981	-1.151	-4.038	0.056	0.057
HH2-628	628	-1.449	-4.227	2/15/03						
HH2-629	629	-0.181	-4.072	2/15/03						
HH2-630	630	0.302	-4.015	2/15/03						
HH2-631	631	-0.214	-4.015	2/19/03						
HH2-632	632	-1.895	-4.241	2/19/03						
HH2-633	633	-2.708	-4.339	2/19/03	-2.699	-4.292	-2.716	-4.385	0.017	0.093
HH2-634	634	-1.027	-4.172	2/19/03						
HH2-635	635	-0.603	-4.102	2/19/03						
HH2-636	636	-1.624	-4.038	2/19/03						
HH2-637	637	-1.992	-4.047	2/19/03						
HH2-638	638	-1.511	-4.131	2/19/03						
HH2-639	639	-0.424	-4.069	2/19/03						
HH2-640	640	-0.083	-3.967	2/19/03						
HH2-641	641	-0.821	-3.851	2/19/03	-0.901	-3.868	-0.74	-3.833	0.161	0.035
HH2-642	642	-1.432	-4.014	2/19/03						
									Average 0.08	Average 0.06

Sample	Depth (mm)	δ13C per mil.	δ18O per mil.	Analysis date	Rep. δ13C	Rep. δ18O	Rep. δ13C	Rep. δ18O	Rep. δ13C diff.	Rep. δ18O diff.
WB-1	1	-1.202	-4.262	1/24/04						
WB-2	2	-1.150	-4.254	1/24/04						
WB-3	3	-1.694	-4.236	1/24/04	-1.622	-4.26	-1.765	-4.212	0.143	0.048
WB-4	4	-2.069	-4.406	2/11/04						
WB-5	5	-1.706	-4.463	1/24/04						
WB-6	6	-1.147	-4.187	1/24/04						
WB-7	7	-1.041	-4.339	1/24/04						
WB-8	8	-1.102	-4.213	1/24/04						
WB-9	9	-1.346	-4.232	1/24/04						
WB-10	10	-1.804	-4.293	1/24/04						
WB-11	11	-1.994	-4.145	1/24/04	-2.011	-4.139	-1.977	-4.151	0.034	0.012
WB-12	12	-2.078	-4.268	1/24/04						
WB-13	13	-2.288	-4.390	1/24/04						
WB-14	14	-2.260	-4.416	1/24/04						
WB-15	15	-2.609	-4.367	1/24/04						
WB-16	16	-2.189	-4.470	1/24/04						
WB-17	17	-1.279	-4.398	1/24/04						
WB-18	18	-0.754	-4.259	1/24/04						
WB-19	19	-0.030	-4.214	1/24/04	-0.026	-4.17	-0.034	-4.258	0.008	0.088
WB-20	20	-0.174	-4.187	1/24/04						
WB-21	21	-0.627	-4.157	1/24/04						
WB-22	22	-1.039	-4.281	1/24/04						
WB-23	23	-0.464	-4.209	1/24/04						
WB-24	24	-0.042	-4.019	1/24/04						
WB-25	25	-0.756	-3.986	1/24/04						
WB-26	26	-1.471	-4.136	1/24/04						
WB-27	27	-1.590	-4.217	1/24/04	-1.631	-4.204	-1.548	-4.229	0.083	0.025
WB-28	28	-1.603	-4.456	1/24/04						
WB-29	29	-1.423	-4.244	1/24/04						
WB-30	30	-1.482	-4.276	1/24/04						
WB-31	31	-1.817	-4.229	1/26/04						
WB-32	32	-1.974	-4.169	1/26/04						
WB-33	33	-2.055	-4.335	1/26/04	-2.034	-4.328	-2.075	-4.341	0.041	0.013
WB-34	34	-2.036	-4.516	1/26/04						
WB-35	35	-1.887	-4.422	1/26/04						
WB-36	36	-1.997	-4.403	1/26/04						
WB-37	37	-1.769	-4.238	1/26/04						
WB-38	38	-1.532	-4.148	1/26/04						
WB-39	39	-1.513	-4.277	1/26/04						
WB-40	40	-1.554	-4.113	1/26/04						
WB-41	41	-1.551	-4.151	2/11/04	-1.559	-4.147	-1.542	-4.155	0.017	0.008
WB-42	42	-1.541	-4.217	1/26/04						
WB-43	43	-1.364	-4.239	1/26/04						
WB-44	44	-1.222	-4.397	1/26/04						
WB-45	45	-1.051	-4.381	1/26/04						
WB-46	46	-0.902	-4.299	1/26/04						
WB-47	47	-0.771	-4.315	1/26/04						
WB-48	48	-0.528	-4.273	1/26/04						
WB-49	49	-0.547	-4.279	1/26/04	-0.48	-4.303	-0.614	-4.254	0.134	0.049
WB-50	50	-0.717	-4.465	1/26/04						
WB-51	51	-0.700	-4.438	1/26/04						
WB-52	52	-0.757	-4.368	1/26/04						
WB-53	53	-0.804	-4.248	1/26/04						
WB-54	54	-1.288	-4.512	1/26/04						
WB-55	55	-1.260	-4.449	1/26/04						
WB-56	56	-1.505	-4.427	1/26/04						
WB-57	57	-1.695	-4.467	1/26/04	-1.74	-4.483	-1.65	-4.45	0.09	0.033
WB-58	58	-1.697	-4.679	1/26/04						
WB-59	59	-0.996	-4.491	2/11/04						
WB-60	60	-0.728	-4.275	1/26/04						
WB-61	61	-1.280	-4.520	1/27/04						
WB-62	62	-1.390	-4.325	1/27/04						
WB-63	63	-1.483	-4.500	1/27/04	-1.502	-4.483	-1.464	-4.516	0.038	0.033
WB-64	64	-1.380	-4.526	1/27/04						
WB-65	65	-1.487	-4.708	1/27/04						
WB-66	66	-1.431	-4.651	1/27/04						
WB-67	67	-0.518	-4.300	1/27/04						
WB-68	68	-0.603	-4.129	1/27/04						
WB-69	69	-1.028	-4.309	1/27/04						
WB-70	70	-1.423	-4.354	1/27/04						
WB-71	71	-1.571	-4.447	1/27/04	-1.57	-4.479	-1.571	-4.415	0.001	0.064
WB-72	72	-1.415	-4.396	1/27/04						
WB-73	73	-1.556	-4.510	1/27/04						
WB-74	74	-1.513	-4.482	1/27/04						
WB-75	75	-1.460	-4.560	1/27/04						
WB-76	76	-1.270	-4.313	2/11/04						
WB-77	77	-1.262	-4.325	1/27/04						
WB-78	78	-1.404	-4.327	1/27/04						
WB-79	79	-1.927	-4.296	1/27/04	-1.953	-4.264	-1.9	-4.328	0.053	0.064
WB-80	80	-2.252	-4.434	1/27/04						
WB-81	81	-2.487	-4.231	1/27/04						
WB-82	82	-2.675	-4.366	1/27/04						
WB-83	83	-3.090	-4.425	1/27/04						
WB-84	84	-3.459	-4.398	1/27/04						
WB-85	85	-3.788	-5.054	2/11/04						
WB-86	86	-3.701	-4.453	2/11/04						
WB-87	87	-3.618	-4.427	1/27/04						
WB-88	88	-3.313	-4.850	1/27/04						

WB-89	89	-1.295	-4.510	1/27/04						
WB-90	90	-1.948	-4.350	1/27/04						
WB-91	91	0.009	-4.136	1/28/04						
WB-92	92	-0.618	-4.151	1/28/04						
WB-93	93	-1.260	-4.456	1/28/04	-1.166	-4.471	-1.353	-4.44	0.187	0.031
WB-94	94	-0.379	-4.484	1/28/04						
WB-95	95	-0.703	-4.243	1/28/04						
WB-96	96	-1.026	-4.154	1/28/04						
WB-97	97	-1.293	-4.351	1/28/04						
WB-98	98	-1.606	-4.500	1/28/04						
WB-99	99	-1.750	-4.722	1/28/04						
WB-100	100	-1.605	-4.709	1/28/04						
WB-101	101	-1.267	-4.647	1/28/04	-1.25	-4.658	-1.284	-4.636	0.034	0.022
WB-102	102	-1.056	-4.608	1/28/04						
WB-103	103	-0.830	-4.322	1/28/04						
WB-104	104	-1.356	-4.331	1/28/04						
WB-105	105	-1.440	-4.241	1/28/04						
WB-106	106	-1.408	-4.230	1/28/04						
WB-107	107	-1.164	-4.198	1/28/04						
WB-108	108	-0.771	-4.255	1/28/04						
WB-109	109	-0.383	-4.135	1/28/04	-0.315	-4.14	-0.45	-4.13	0.135	0.01
WB-110	110	-0.253	-4.111	1/28/04						
WB-111	111	-0.681	-4.104	1/28/04						
WB-112	112	-1.255	-4.180	1/28/04						
WB-113	113	-1.476	-4.243	2/11/04						
WB-114	114	-1.005	-4.469	1/28/04						
WB-115	115	-0.240	-4.447	1/28/04						
WB-116	116	-0.486	-4.342	1/28/04						
WB-117	117	-1.129	-4.258	1/28/04	-1.087	-4.247	-1.171	-4.268	0.084	0.021
WB-118	118	-1.500	-4.271	1/28/04						
WB-119	119	-1.856	-4.418	1/28/04						
WB-120	120	-1.873	-4.461	1/28/04						
WB-121	121	-1.337	-4.554	1/29/04						
WB-122	122	-0.769	-4.483	1/29/04						
WB-123	123	-0.559	-4.463	1/29/04	-0.569	-4.456	-0.549	-4.469	0.02	0.013
WB-124	124	-0.584	-4.457	1/29/04						
WB-125	125	-0.731	-4.415	1/29/04						
WB-126	126	-0.954	-4.466	1/29/04						
WB-127	127	-1.301	-4.432	1/29/04						
WB-128	128	-0.616	-4.284	1/29/04						
WB-129	129	-0.097	-4.191	1/29/04						
WB-130	130	-0.753	-4.252	1/29/04						
WB-131	131	-0.933	-4.337	1/29/04	-0.962	-4.31	-0.903	-4.363	0.059	0.053
WB-132	132	-1.329	-4.389	1/29/04						
WB-133	133	-1.449	-4.494	1/29/04						
WB-134	134	-1.520	-4.442	1/29/04						
WB-135	135	-0.813	-4.368	1/29/04						
WB-136	136	-0.358	-4.210	1/29/04						
WB-137	137	-0.135	-4.095	1/29/04						
WB-138	138	-0.442	-4.108	1/29/04						
WB-139	139	-0.889	-4.280	1/29/04	-0.937	-4.272	-0.84	-4.288	0.097	0.016
WB-140	140	-0.950	-4.490	1/29/04						
WB-141	141	-0.161	-4.232	1/29/04						
WB-142	142	-0.209	-4.238	1/29/04						
WB-143	143	-0.872	-4.203	1/29/04						
WB-144	144	-1.462	-4.285	1/29/04						
WB-145	145	-1.844	-4.583	1/29/04						
WB-146	146	-1.863	-4.653	1/29/04						
WB-147	147	-1.559	-4.761	1/29/04	-1.607	-4.845	-1.511	-4.677	0.096	0.168
WB-148	148	-1.010	-4.590	1/29/04						
WB-149	149	-1.520	-4.640	1/29/04						
WB-150	150	-1.134	-4.347	1/29/04						
WB-151	151	-0.942	-4.362	2/2/04						
WB-152	152	-1.055	-4.386	2/2/04						
WB-153	153	-1.257	-4.384	2/2/04	-1.2384	-4.36	-1.275	-4.407	0.0366	0.047
WB-154	154	-1.074	-4.534	2/2/04						
WB-155	155	-0.755	-4.343	2/2/04						
WB-156	156	-0.790	-4.275	2/2/04						
WB-157	157	-1.004	-4.343	2/2/04						
WB-158	158	-0.980	-4.420	2/2/04						
WB-159	159	-0.838	-4.328	2/11/04						
WB-160	160	-1.033	-4.412	2/11/04						
WB-161	161	-1.120	-4.565	2/2/04						
WB-162	162	-1.393	-4.630	2/11/04						
WB-163	163	-0.154	-4.959	2/11/04						
WB-164	164	-0.754	-4.150	2/2/04						
WB-165	165	-1.083	-4.390	2/2/04						
WB-166	166	-1.047	-4.532	2/2/04						
WB-167	167	-0.523	-4.424	2/2/04						
WB-168	168	-0.096	-4.186	2/2/04						
WB-169	169	-0.549	-4.298	2/2/04	-0.535	-4.304	-0.562	-4.292	0.027	0.012
WB-170	170	-0.744	-4.266	2/2/04						
WB-171	171	-1.055	-4.366	2/2/04						
WB-172	172	-1.475	-4.470	2/2/04						
WB-173	173	-1.075	-4.428	2/2/04						
WB-174	174	-0.788	-4.554	2/2/04						
WB-175	175	-0.566	-4.474	2/2/04						
WB-176	176	-0.640	-4.203	2/2/04						
WB-177	177	-0.861	-4.257	2/2/04	-0.945	-4.251	-0.776	-4.262	0.169	0.011

WB-178	178	-0.811	-4.172	2/2/04						
WB-179	179	-0.983	-4.198	2/2/04						
WB-180	180	-0.943	-4.198	2/2/04						
WB-181	181	-1.090	-3.886	2/4/04						
WB-182	182	-1.492	-4.317	2/4/04						
WB-183	183	-1.417	-4.414	2/4/04	-1.424	-4.385	-1.409	-4.442	0.015	0.057
WB-184	184	-0.892	-4.428	2/4/04						
WB-185	185	-0.626	-4.530	2/4/04						
WB-186	186	-0.252	-4.026	2/4/04						
WB-187	187	-0.855	-4.204	2/4/04						
WB-188	188	-0.787	-4.081	2/4/04						
WB-189	189	-1.226	-4.112	2/4/04						
WB-190	190	-1.246	-4.067	2/4/04						
WB-191	191	-1.254	-4.233	2/4/04	-1.216	-4.247	-1.292	-4.218	0.076	0.029
WB-192	192	-0.957	-4.325	2/4/04						
WB-193	193	-1.044	-4.435	2/4/04						
WB-194	194	-0.810	-4.460	2/4/04						
WB-195	195	-0.646	-4.300	2/4/04						
WB-196	196	-0.573	-4.260	2/4/04						
WB-197	197	-0.558	-4.094	2/4/04						
WB-198	198	-0.388	-4.123	2/4/04						
WB-199	199	-0.511	-4.076	2/4/04	-0.539	-4.059	-0.482	-4.092	0.057	0.033
WB-200	200	-0.704	-4.062	2/4/04						
WB-201	201	-1.228	-4.327	2/4/04						
WB-202	202	-1.436	-4.326	2/4/04						
WB-203	203	-1.314	-4.384	2/4/04						
WB-204	204	-0.697	-4.286	2/4/04						
WB-205	205	-0.589	-4.077	2/4/04						
WB-206	206	-0.614	-4.171	2/4/04						
WB-207	207	-0.686	-4.034	2/4/04	-0.708	-4.038	-0.663	-4.03	0.045	0.008
WB-208	208	-0.710	-4.071	2/4/04						
WB-209	209	-0.886	-4.124	2/4/04						
WB-210	210	-1.103	-4.007	2/4/04						
WB-211	211	-1.572	-4.120	2/5/04						
WB-212	212	-1.784	-4.193	2/5/04						
WB-213	213	-0.511	-4.076	2/5/04	-1.905	-4.222	-1.825	-4.154	0.08	0.068
WB-214	214	-1.395	-4.289	2/5/04						
WB-215	215	-0.634	-4.117	2/5/04						
WB-216	216	0.002	-3.853	2/5/04						
WB-217	217	-0.462	-3.765	2/5/04						
WB-218	218	-1.020	-3.844	2/5/04						
WB-219	219	-1.589	-3.897	2/5/04						
WB-220	220	-1.565	-3.991	2/5/04						
WB-221	221	-0.511	-4.076	2/5/04	-1.827	-4.046	-2.017	-4.102	0.19	0.056
WB-222	222	-1.898	-4.101	2/5/04						
WB-223	223	-1.918	-4.201	2/5/04						
WB-224	224	-1.614	-4.209	2/5/04						
WB-225	225	-1.228	-4.163	2/5/04						
WB-226	226	-0.890	-3.943	2/5/04						
WB-227	227	-1.028	-4.049	2/5/04						
WB-228	228	-1.194	-4.116	2/5/04						
WB-229	229	-0.511	-4.076	2/5/04	-1.011	-4.025	-0.869	-3.925	0.142	0.1
WB-230	230	-1.248	-4.018	2/5/04						
WB-231	231	-1.726	-4.153	2/5/04						
WB-232	232	-1.683	-4.195	2/5/04						
WB-233	233	-1.891	-4.485	2/5/04						
WB-234	234	-1.456	-4.535	2/11/04						
WB-235	235	-1.116	-4.596	2/5/04						
WB-236	236	-1.169	-4.349	2/11/04						
WB-237	237	-1.140	-4.183	2/11/04	-1.149	-4.228	-1.13	-4.138	0.019	0.09
WB-238	238	-1.105	-4.107	2/11/04						
WB-239	239	-1.399	-4.191	2/5/04						
WB-240	240	-1.702	-4.197	2/11/04						
WB-241	241	-1.930	-4.201	2/9/04						
WB-242	242	-1.960	-4.171	2/9/04						
WB-243	243	-2.008	-4.364	2/9/04	-2.009	-4.405	-2.007	-4.323	0.002	0.082
WB-244	244	-1.781	-4.265	2/9/04						
WB-245	245	-1.702	-4.444	2/9/04						
WB-246	246	-1.502	-4.431	2/9/04						
WB-247	247	-1.410	-4.286	2/9/04						
WB-248	248	-1.185	-4.110	2/9/04						
WB-249	249	-1.509	-4.130	2/9/04						
WB-250	250	-1.478	-4.160	2/9/04						
WB-251	251	-1.567	-4.092	2/9/04	-1.578	-4.111	-1.556	-4.072	0.022	0.039
WB-252	252	-1.937	-4.226	2/9/04						
WB-253	253	-2.078	-4.165	2/9/04						
WB-254	254	-2.206	-4.099	2/9/04						
WB-255	255	-2.062	-4.142	2/9/04						
WB-256	256	-1.580	-4.469	2/9/04						
WB-257	257	-1.048	-4.452	2/9/04						
WB-258	258	-0.853	-4.429	2/9/04						
WB-259	259	-0.931	-4.267	2/9/04	-0.931	-4.224	-0.931	-4.31	0	0.086
WB-260	260	-1.512	-4.301	2/9/04						
WB-261	261	-1.523	-4.072	2/9/04						
WB-262	262	-1.595	-4.033	2/9/04						
WB-263	263	-1.356	-3.787	2/9/04						
WB-264	264	-1.606	-4.009	2/9/04						
WB-265	265	-1.580	-4.241	2/9/04						
WB-266	266	-1.531	-4.259	2/9/04						

WB-267	267	-1.362	-4.319	2/9/04	-1.359	-4.304	-1.365	-4.333	0.006	0.029
WB-268	268	-0.987	-4.295	2/9/04						
WB-269	269	-0.808	-4.336	2/9/04						
WB-270	270	-0.626	-4.127	2/9/04						
WB-271	271	-0.562	-4.010	2/10/04						
WB-272	272	-1.008	-4.104	2/10/04						
WB-273	273	-1.092	-4.020	2/10/04	-1.094	-3.949	-1.089	-4.091	0.005	0.142
WB-274	274	-0.698	-3.833	2/10/04						
WB-275	275	-0.881	-3.995	2/10/04						
WB-276	276	-1.042	-4.101	2/10/04						
WB-277	277	-1.160	-4.170	2/10/04						
WB-278	278	-0.943	-4.215	2/10/04						
WB-279	279	-0.258	-4.184	2/10/04						
WB-280	280	-0.130	-4.057	2/10/04						
WB-281	281	-0.424	-3.964	2/10/04	-0.139	-3.975	-0.708	-3.952	0.569	0.023
WB-282	282	-0.883	-3.949	2/10/04						
WB-283	283	-0.877	-3.920	2/10/04						
WB-284	284	-0.892	-3.983	2/10/04						
WB-285	285	-1.025	-4.104	2/10/04						
WB-286	286	-1.050	-4.083	2/10/04						
WB-287	287	-0.974	-4.165	2/10/04						
WB-288	288	-0.733	-4.154	2/10/04						
WB-289	289	-0.728	-4.163	2/10/04	-0.824	-4.161	-0.631	-4.165	0.193	0.004
WB-290	290	-0.609	-4.140	2/10/04						
WB-291	291	-0.569	-4.213	2/10/04						
WB-292	292	-0.445	-4.087	2/10/04						
WB-293	293	-0.512	-4.151	2/10/04						
WB-294	294	-0.639	-4.226	2/10/04						
WB-295	295	-0.706	-4.138	2/10/04						
WB-296	296	-0.693	-4.071	2/10/04						
WB-297	297	-0.747	-4.118	2/10/04	-0.787	-4.13	-0.706	-4.105	0.081	0.025
WB-298	298	-0.720	-4.091	2/10/04						
WB-299	299	-0.589	-3.986	2/10/04						
WB-300	300	-0.972	-3.981	2/10/04						
									Average 0.08	Average 0.05

APPENDIX 2: TRACE ELEMENT DATA

Punalu'u Age	Cu (ppm)	Zn (ppm)	Sn (ppm)	La (ppm)	Ce (ppm)	Pb (ppm)	U (ppm)	Al (ppm)	Fe (ppm)
2002	2.562	3.210	0.346	0.003	0.003	0.219	3.476	4.593	66.718
2001	5.744	1.888	0.662	0.002	0.003	0.549	3.132	128.122	205.483
2000	2.635	2.156	0.303	0.001	0.002	0.122	3.035	3.702	136.875
1999	2.295	1.054	0.290	0.001	0.002	0.060	2.862	2.140	21.385
1998	1.635	0.952	0.300	0.002	0.002	0.107	3.139	1.794	11.678
1997	1.580	1.144	0.144	0.002	0.002	0.210	2.977	45.715	31.376
1996	3.585	1.321	0.431	0.002	0.004	1.065	2.812	189.996	103.919
1995	2.228	1.335	0.414	0.002	0.004	0.820	3.390	16.341	13.582
1994	2.451	1.733	0.874	0.002	0.003	0.661	3.117	3.481	11.590
1993	4.864	5.507	0.753	0.004	0.008	0.674	3.305	399.623	106.751
1992	5.740	2.763	0.872	0.004	0.008	1.799	3.143	6.014	91.777
1991	5.553	2.425	1.176	0.003	0.005	0.308	3.215	2.975	15.061
1990	4.747	3.619	1.006	0.002	0.002	0.511	3.417	1.985	9.059
1989	8.557	1.051	1.738	0.002	0.039	1.172	2.974	2.256	4.781
1988	12.205	6.356	1.694	0.002	0.004	0.247	2.876	2.057	5.186
1987	5.709	1.394	1.178	0.003	0.006	0.163	3.024	2.607	20.183
1986	4.110	1.229	0.814	0.001	0.002	0.055	3.222	1.706	4.284
1985	3.958	5.668	0.910	0.002	0.002	0.082	2.819	2.938	6.591
1984	3.763	1.209	0.705	0.001	0.002	0.090	3.413	2.184	8.075
1983	4.592	2.852	0.805	0.002	0.006	0.121	3.396	5.470	47.050
1982	4.302	1.644	0.695	0.002	0.004	0.132	3.505	4.652	40.818
1981	4.084	1.611	0.773	0.002	0.004	0.126	3.292	2.919	16.046
1980	5.142	1.254	0.959	0.001	0.002	0.281	3.124	2.090	6.849
1979	6.793	1.295	1.408	0.001	0.003	0.418	3.117	2.682	5.333
1978	2.774	1.220	0.571	0.001	0.002	0.160	3.107	4.387	16.671
1977	4.454	1.834	0.695	0.003	0.006	1.342	2.846	9.032	103.633
1976	5.330	1.161	0.717	0.001	0.003	5.297	3.274	4.805	44.168
1975	3.310	1.449	0.481	0.002	0.003	2.506	3.014	9.755	36.339
1974	8.171	3.764	0.961	0.002	0.004	1.356	3.519	8.367	34.308
1973	6.092	4.521	1.040	0.004	0.005	1.650	3.098	5.163	21.733
1972	3.869	1.411	0.674	0.002	0.004	1.591	3.137	3.568	17.452
1971	3.052	4.504	0.601	0.002	0.002	0.750	2.924	2.962	8.517
1970	2.523	1.795	0.410	0.002	0.001	0.651	3.145	3.083	5.101
1969	2.727	1.010	0.496	0.001	0.003	1.335	3.053	1.971	2.986
1968	2.374	1.303	0.354	0.001	0.003	1.986	3.001	18.313	9.774
1967	2.151	1.425	0.337	0.001	0.002	2.020	3.062	1.921	2.046
1966	2.027	1.258	0.328	0.001	0.002	2.370	3.005	2.197	1.427
1965	1.919	1.006	0.265	0.001	0.002	3.968	3.142	2.140	2.206
1964	2.561	1.120	0.347	0.002	0.003	1.102	3.408	1.804	3.135
1963	2.118	1.195	0.291	0.004	0.005	0.255	3.212	17.269	5.634
1962	2.247	1.293	0.267	0.003	0.004	0.210	3.125	1.879	2.183
1961	1.466	1.287	0.164	0.002	0.004	0.171	3.215	1.712	2.561
1960	5.260	1.626	1.057	0.002	0.002	1.753	3.251	1.897	2.582
1959	3.699	2.585	0.610	0.002	0.002	0.857	3.294	5.551	19.680
1958	3.754	1.374	0.757	0.001	0.003	0.475	3.219	2.048	29.613
1957	4.224	1.259	0.821	0.002	0.003	0.236	2.790	2.457	5.516
1956	5.104	1.147	0.341	0.002	0.002	1.122	3.015	310.398	4.339
1955	6.361	1.430	0.749	0.002	0.002	1.563	2.987	291.800	5.596
1954	23.855	1.181	0.635	0.002	0.002	3.733	2.142	1511.313	15.622
1953	4.830	1.229	1.052	0.001	0.001	0.101	3.356	1.917	5.064
1952	6.475	1.407	1.132	0.001	0.001	0.089	3.457	1.552	2.754
1951	5.351	1.332	1.081	0.001	0.002	0.146	3.290	1.884	5.298
1950	3.527	1.472	0.973	0.003	0.006	0.212	3.022	6.072	54.226
1949	3.115	1.404	0.526	0.001	0.001	0.515	3.196	2.296	19.950
1948	3.237	1.336	0.625	0.001	0.002	0.292	3.133	2.123	14.954
1947	3.453	1.084	0.534	0.001	0.003	2.023	3.064	29.079	6.599
1946	3.352	1.346	0.592	0.001	0.002	0.508	3.373	9.708	12.700
1945	6.897	3.135	0.564	0.003	0.003	3.879	2.941	198.624	56.864
1944	2.890	13.735	0.409	0.004	0.007	0.204	2.945	9.806	127.972

Waikiki Age	Cu (ppm)	Zn (ppm)	Sn (ppm)	La (ppm)	Ce (ppm)	Pb (ppm)	U (ppm)	Al (ppm)	Fe (ppm)
2003	3.595	10.026	0.084	0.003	0.002	0.393	2.759	4.201	69.050
2002	76.123	2.188	0.306	0.003	0.003	0.840	2.680	4.697	170.705
2001	2.600	1.515	0.190	0.003	0.002	0.318	2.544	4.691	77.152
2000	3.214	1.446	0.170	0.003	0.002	0.339	2.326	4.630	98.988
1999	3.671	1.584	0.221	0.003	0.003	0.707	2.457	5.108	81.542
1998	4.739	1.620	0.434	0.004	0.003	0.658	2.419	17.015	196.718
1997	3.265	1.150	0.107	0.003	0.003	0.260	2.291	6.053	28.417
1996	279.322	1.682	0.234	0.004	0.004	0.460	2.403	8.615	52.178
1995	6.024	2.243	0.523	0.003	0.004	1.000	2.598	9.998	261.752
1994	3.799	2.247	0.388	0.003	0.002	0.718	2.435	4.161	150.693
1993	4.873	2.423	0.470	0.003	0.003	0.776	2.461	3.321	114.968
1992	19.540	9.456	0.327	0.006	0.008	1.046	2.338	7.483	79.486
1991	3.768	1.573	0.990	0.003	0.003	0.582	2.508	5.631	61.591
1990	2.061	1.728	0.104	0.004	0.002	0.335	2.684	3.577	395.222
1989	2.677	2.104	0.153	0.004	0.005	0.496	2.592	6.738	45.779
1988	1.978	1.602	0.087	0.002	0.002	0.287	2.621	2.591	28.727
1987	2.938	1.823	0.237	0.004	0.003	0.424	2.431	4.472	35.795
1986	8.330	1.977	0.111	0.003	0.003	0.530	2.740	3.115	24.078
1985	1.759	1.198	0.110	0.003	0.003	0.546	2.782	3.460	24.578
1984	2.092	1.434	0.167	0.003	0.003	0.885	2.892	2.922	48.471
1983	2.043	1.394	0.405	0.003	0.002	1.107	2.882	3.552	46.082
1982	2.989	2.384	0.178	0.003	0.004	1.311	2.684	4.283	75.003
1981	3.538	1.600	0.368	0.002	0.002	1.662	3.118	4.710	168.819
1980	3.509	1.763	0.219	0.003	0.003	2.081	3.356	3.857	84.899
1979	2.481	1.690	0.334	0.002	0.002	0.575	2.572	8.769	56.385
1978	2.714	1.701	0.237	0.003	0.002	0.515	2.639	4.033	73.172
1977	2.978	1.716	0.234	0.003	0.003	0.603	2.932	5.008	93.833
1976	2.809	1.883	0.335	0.003	0.003	0.600	3.117	8.192	92.067
1975	1.819	1.371	0.334	0.004	0.003	0.438	2.875	2.832	39.695
1974	1.332	1.503	0.108	0.003	0.003	0.371	3.152	2.268	37.347

APPENDIX 3: Sr/Ca Data

Depth (mm)	Sr/Ca, mass	Sr/Ca, molar
1	43.87	
2	20.44	9.35
3	20.35	9.31
4	20.50	9.38
5	19.55	8.94
6	20.38	9.32
7	20.48	9.37
8	20.50	9.38
9	20.40	9.33
10	20.40	9.33
11	20.43	9.35
12	63.28	
13	20.18	9.23
14	20.17	9.23
15	20.17	9.23
16	20.37	9.32
17	20.53	9.39
18	20.68	9.46
19	20.65	9.45
20	20.82	9.52
21	20.74	9.49
22	20.59	9.42
23	20.58	9.41
24	20.38	9.32
25	20.54	9.40
26	20.64	9.44
27	20.70	9.47
28	21.20	9.70
29	21.18	9.69
30	20.31	9.29
31	20.17	9.23
32	20.21	9.24
33	20.18	9.23
34	19.99	9.15
35	20.21	9.25
36	20.08	9.18
37	20.13	9.21
38	19.89	9.10
39	19.78	9.05
40	20.31	9.29
41	20.04	9.17
42	20.37	9.32
43	20.01	9.15
44	20.18	9.23
45	20.07	9.18
46	20.08	9.19
47	20.17	9.23
48	20.07	9.18
49	20.19	9.24
50	20.25	9.26
51	20.27	9.27
52	19.98	9.14

53	19.96	9.13
54	19.86	9.09
55	19.92	9.11
56	19.83	9.07
57	20.06	9.17
58	20.21	9.25
59	20.22	9.25
60	20.09	9.19
61	20.19	9.23
62	20.36	9.31
63	20.09	9.19
64	19.63	8.98
65	19.94	9.12
66	20.05	9.17
67	19.81	9.06
68	19.97	9.14
69	19.72	9.02
70	19.89	9.10
71	20.10	9.20
72	20.00	9.15
73	20.17	9.23
74	20.03	9.16
75	20.12	9.20
76	20.01	9.16
78	20.08	9.18
79	20.01	9.16
80	19.99	9.15
81	20.13	9.21
82	19.99	9.14
83	20.27	9.27
84	20.27	9.27
85	20.56	9.41
86	20.22	9.25
87	20.13	9.21
88	20.20	9.24
89	20.23	9.26
90	20.30	9.28
91	20.44	9.35
92	20.44	9.35
93	20.03	9.16
94	20.21	9.25
95	20.06	9.18
96	20.21	9.25
97	20.35	9.31
98	20.39	9.33
99	20.42	9.34
100	20.15	9.22
101	20.21	9.24
102	20.12	9.20
103	19.97	9.14
104	20.00	9.15
105	19.87	9.09
106	19.93	9.12

107	20.17	9.23
108	20.04	9.17
109	20.08	9.19
110	20.27	9.27
111	20.20	9.24
112	20.37	9.32
113	20.38	9.32
114	20.52	9.39
115	20.40	9.33
116	20.12	9.21
117	20.00	9.15