Report: The mystery lies in the *Scirpus*

Candace Gossen

This report concerns *Scirpus*, forests, and a quest to find a method for documenting rainfall changes in the ancient past. I begin with the middle.

It was through a conversation with Irving Friedman and we were discussing how obsidian glass captures a moisture signature when it is formed, and then we began to talk about a small island called Marajo, off the coast of Brazil. While flying over the island, Friedman noticed that half of the island was forested while the other half had been clearcut. He subsequently discovered that two-thirds of the annual precipitation that formerly occurred on the island no longer fell. He was certain that it was due to deforestation, and I agreed. I knew that when I walked through a forest I could feel the respiration of the leaves. I noted this growing up in the bayous of Louisiana, in the forests of the northwest, in the rainforests of Belize and Guatemala, and in my travels around the world. But now science was demanding a method to show proof that this was true.

Truth and science are all about how you ask the questions, and finding the right method is limited to how creative we are. I did not then find the answers in obsidian. But I have begun an adventure that has taken me to coring lakes and, more particularly, the crater lakes on Rapa Nui.

In March 2005, through great effort and serendipity, John Flenley and David Meek of Massey University, and Rob Dunbar of Stanford and his coral-coring team, were all on the island at the same time as I was. All of us were looking for more pieces to the mystery of Rapa Nui, its past climate, and trying to understand the human connection to this island.

My focus was the crater lakes and, more particularly, Rano Kau. It was at this crater where the last tree was seen on the island, and it was also where Thor Heyerdahl and his expedition team in 1955 discovered (through pollen samples) that the island had supported a sub-tropical palm forest. It was the changes in the forest that drew me here, and what I am searching for is a direct method to test moisture variations in the ancient past.

The climate history of the island is mostly unknown and a great deal of speculation about human impact and environmental degradation has been made considering the lack of information. We all would like to know when humans arrived on the island and whether they had sufficient impact on the natural environment to cause culture failure. But are we missing something really important, like climate? Because of Rapa Nui's isolation from a large land mass, the ecosystem is closed and altering one thing changes everything. In order to understand ecology we must look at all the connections and this type of research requires a multi-disciplinary approach. Deductively, over the last two years, I have tried method after method to obtain as much information as I can.

THE CORE

My subject is called KAO05-3A, located approximately 400 meters from the northwest edge of Rano Kau's lake at 27°11'37" S, 109°26'3" W and 522 meters (as a crow flies) from the *mirador* at the rim. My first observation was that the floating mat of vegetation showed an elevation of 110 meters, or six meters higher than the noted 104m elevation on the 1992 *Armada de Chile* map, and two meters more water-depth than John Flenley found in his coring in the late 1980s. The KAO05-3A core includes a 2m core of floating *totora*[1] (*Scirpus*) and *Polygonum acuminatum* mat, and nine meters of lake sediment that reached to a clay bottom. Between them are 10.5 meters of water. The grand total of the core was 21.5 meters from the top of mat to clay at the KAO05-3A coring point.

Like most common testing of lake sediment cores, I began with the Initial Core Description (ICD) that consists of nondestructive measurement of bulk sediment properties, division of the core into working and archive halves, imaging of the whole core, and macro- and microscopic identification of sedimentary structures and composition. This process was conducted at the LacCore Limnological Research Center (LRC) at the University of Minnesota in Minneapolis.

The low-resolution magnetic susceptibility scan set up the beginning investigation. It was found that down-core magnetic susceptibility peaks are linked to periods of deforestation and the subsequent erosion of mineral soils. The variations in the amplitude of the magnetic susceptibility record could be used as a proxy indicator of the intensity of erosion.

In this scan, peaks of high susceptibility were noted and further refined with the high-resolution scans that followed at 0.5mm intervals once the core was opened. What we found in the low-resolution scan were five very distinctive peaks (Figure 1). One was isolated at the 1.7 meter point as referenced from the top of the lake sediment core, and the other four were closely distributed between the 7.0 and 8.0 meters of the core. These were not minor events. The peaks were very pronounced and obvious.

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[1] *Totora* is an introduced South American name for the plant *Scirpus californicus,* in the family *Cyperaceae.* Its correct Rapanui name is *nga'atu*.

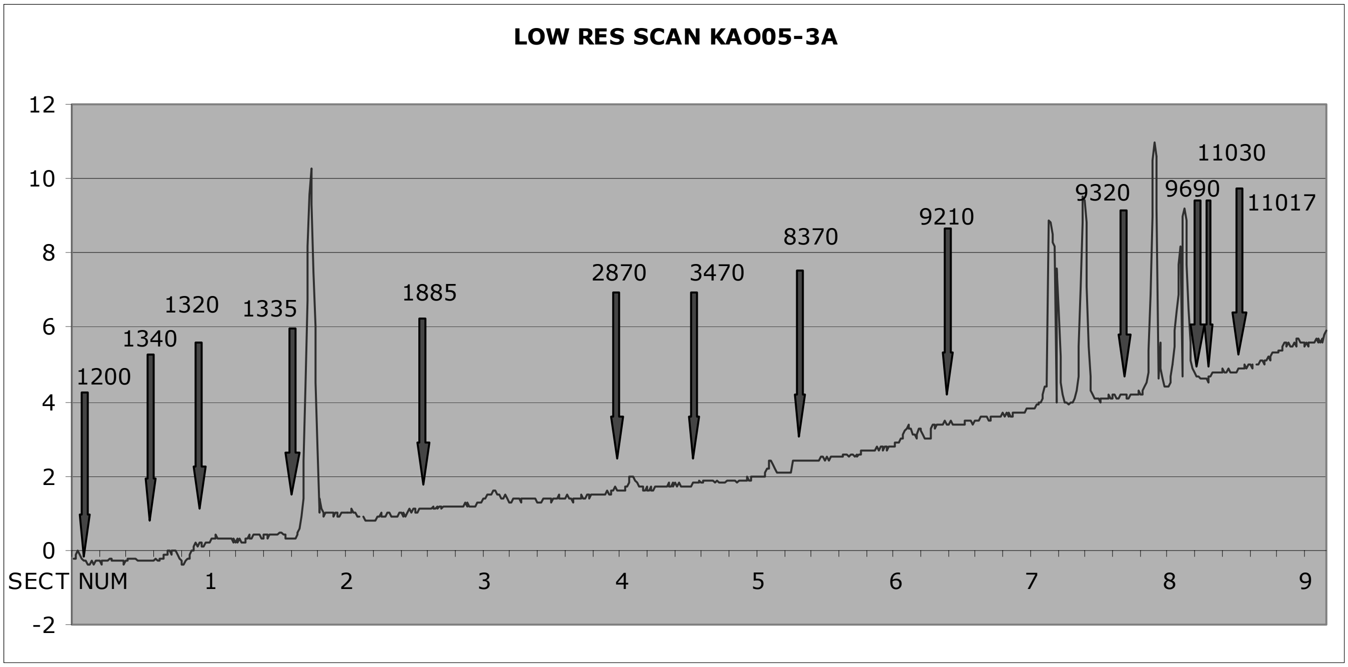

Figure 1. Low resolution magnetic susceptibility scan of KAO05-3A sediment core with arrows indicating ^{14}C dates BC.

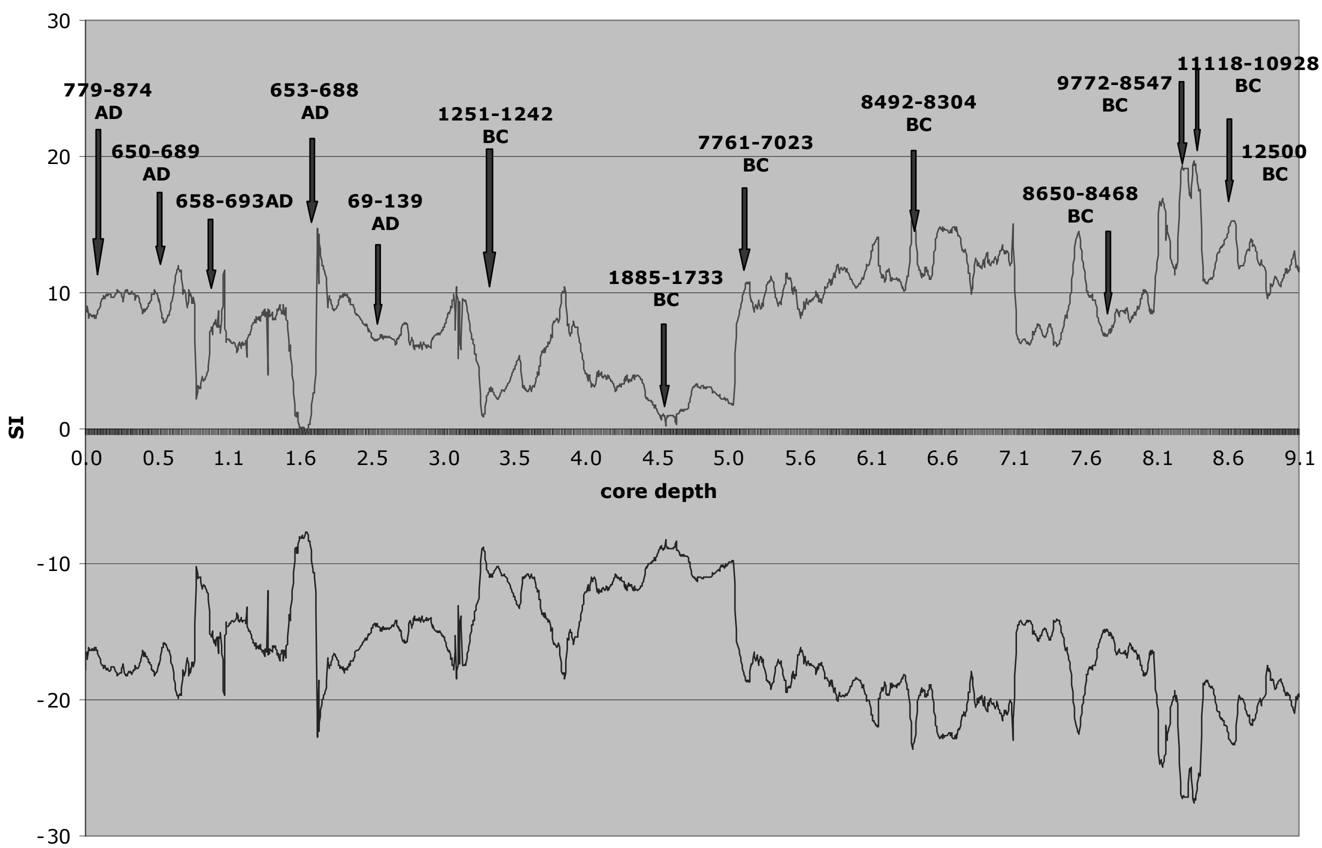

Figure 2. Magnetic susceptibility scan with calibrated radiocarbon dates indicated with arrows..

Overlaying these peaks on the high-resolution scans, I picked 12 points in the core to sample for radiocarbon dating (Figure 2). Something important was happening at these key points and we needed to know their dates. Were the peaks dated to the time that humans were on the island or were they climate anomalies?

RADIOCARBON DATING

The first radiocarbon date processed at the Rafter Radiocarbon Laboratory in Wellington, New Zealand, was sampled above the clay layer for a basal date of ^{14}C 11,017 ± 45 years, with a calibrated date of sigma two interval from 13,058 to 12,868 BP. This was the oldest date in the lake found thus far, and a good start. It was really important at this point to pick the correct item to date by radiocarbon. Did this mean bulk sediment, pollen, or macrofossils? Up to this day, many are still arguing that past radiocarbon dates obtained in the lakes are anomalous and unreliable. Therefore, the first and major effort of this core was to obtain accurate dates with a linear chronology, otherwise all the other data and information would not be reliable.

I knew bulk dating had problems. Noting at first glimpse when I opened the cores that whole *Scirpus* bulbs in the core gave way to inversions. The bulbs were heavier and they would drop through the sediment. Therefore bulk sediment and macrofossils from plant remains would not be reliable. So I began looking for seeds. *Scirpus* seeds. Since the lake was covered with *Scirpus* I wanted to know if there were seeds in each of the twelve samples taken. And yes, we found *Scirpus* in all of them. We only needed two, at minimum, to get an accurate radiocarbon date, as we later found out. The very finding of *Scirpus* seeds in all of the cores and samples supports the evidence that this plant has been growing on the island, at the very least, to the end of the last glacial period.

An email came in June of 2007 and read *"Hey Candace, I do hope you are sitting down. Here are the scirpus seed results. They are in perfect order with the uppermost sample having bomb-^{14}C in it."* The message came from Tom Guilderson of the AMS Lab, Lawrence Livermore National Laboratory, with whom I had been working for over the past year and a half, processing radiocarbon dates. In spring of 2006 I spent a week at the LLNL lab processing twelve samples of *Scirpus* seeds and, running alongside for comparison, were pollen samples taken from the same sample depths (Figure 3). Of the pollen dates, the only confidence was in 5L-1-54-55 which dated 3555 ^{14}C yrs BP. It was here that enough pollen was extracted to obtain a reasonable sample size (200µg of carbon). All of the other pollen extracts were below 100µg. One needs to think seriously when dealing with less than 100µg of carbon because

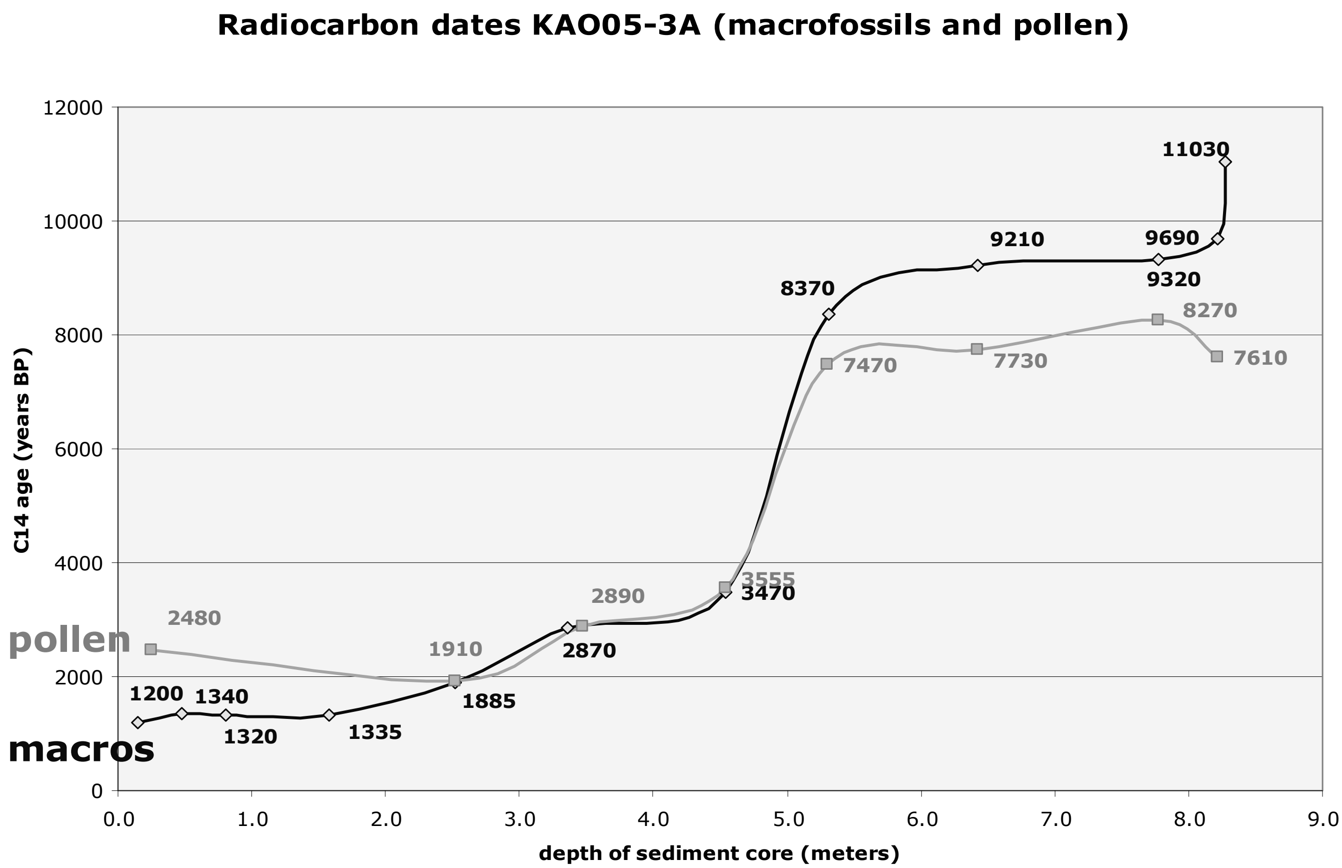

Figure 3. Radiocarbon dates KAO05-3A macro and pollen samples.

it is not known what has been left in the samples from the chemical processing, and a small amount of modern and/or dead carbon will make a significant difference in small samples. For the small macros, *Scirpus* seeds, we knew exactly where they came from (good firm sediment, not soupy and located away from any section breaks and/or edges of the core).

The first set of radiocarbon dates were run only on the lake sediment samples. We knew at this point that the basal date was 11,017 BP ^{14}C but we had no idea what the top of the sediment core would date to. The dates came back with a top of core of 1200 ± 35 ^{14}C date with a calibrated sigma one interval of 779 AD to 874 AD (see Figures 1 and 4 for the complete radiocarbon data on both the mat and sediment core for KAO05-3A).

The last set of dates that Tom referred to in his email were for the floating mat. Until now, all previous dating of the mat had always had inversions, that is, younger dates on the bottom of the mat, and older dates on top. Were the floating mats colliding with each other as they were blown across the lake by wind, and folding over each other? Were sections dying and falling as whole units into the depths of the lake? Whatever was happening, until now no one had obtained clear linear chronology in a mat. With the help of Christopher Stevenson and a grant from the Easter Island Foundation, four samples were taken from the floating mat of my core. The youngest of the dates at top had atomic ^{14}C in it, while the bottom of the mat dated to a conventional ^{14}C of 605 ± 30 and a calibrated date of sigma one interval from 1304 AD to 1397 AD. Still, 400 years of information was slowly decomposing and resting between the bottom of the mat and the top of the sediment core. The floating mat is a curious thing.

THE LAKE

The lake also is curious. Seemingly, it is a closed basin with only rainfall adding to its liquid contents. It is the void leftover from a volcanic eruption 1 million years ago and it has slowly been collecting and evaporating its moisture while providing a unique microclimate within the crater walls. The bottom depth of the lake is unknown, but in this KAO05-3A core we hit a clay layer, that was at least very near to center, and it has given us a date as approximately 13K BP.

At some time in the ancient past *Scirpus* began growing on the lake's surface. Was it planted intentionally in a shallow swamp that existed here, or was it a marginal plant that grew on the edges of the lake and then slowly migrated towards the center over time? However it happened, what we find today is a varying thickness of 2 to 3 meters of floating living plant matter that includes two aquatic plants: S*cirpus* and *Polygonum,* both very useful plants to humans. *Scirpus,* a reed-like plant, provided building materials for many things including boats, and the *Polygonum acuminatum*, a freshwater medicinal plant, has been observed in previous pollen cores and is usually with human occupation. The surface of the lake is mostly covered by these floating nitrogen-rich plant mats that slowly are decomposing into the dark water beneath.

In ecology, it has always been the attempt to classify ecosystems by the biota they support. Biological paleolimnology is an extension that further defines these relationships, and it is these studies of the physical, chemical and biological information stored in lake deposits that color a multi-proxy of past environmental change.

This research continues with identifying pollen and charcoal counts, and expanding the ecological assessment

Table 1. Calibrated radiocarbon dates using Calib v5.1 and IntCal04.

CAMS #	Sample Name	Delta ^{13}C	Fraction Modern	^{14}C Age Macrofossils	Actual Depth m	Calibrated Date Sigma 1	Calibrated Date Sigma 2
132962	KA03 0-5cm	-25	1.1383	45 ± >modern	0.005	modern	modern
132963	KA03 85-90	-25	0.9699	245 ± 40	0.85	1634-1672 AD	1618-1684 AD
132964	KA03 120-125	-25	0.9346	54 5 ± 35	1.2	1394-1425 AD	1386-1437 AD
132965	KA03 195-200	-25	0.9276	605 ± 30	1.95	1338-1364 AD	1297-1405 AD
125890	RNKA05-3A-1L-1W 15-16	-25	0.8610	1200 ± 35	12.65	779-874 AD	765-897 AD
123142	1L-1 48-52	-25	0.8466	1340 ± 35	12.98	650-689 AD	640-725 AD
123143	1L-1 81-82	-28.6	0.8484	1320 ± 30	13.31	658-693 AD	652-725 AD
125893	RNK05-3A-2L-1W 58-60	-25	0.8468	1335 ± 30	14.08	653-688 AD	646-719 AD
123145	3L-1 52-54	-25	0.7907	1885 ± 35	15.02	70-138 AD	61-219 AD
125891	RNKA05-3A-4L-1W 36-37	-25	0.6998	2870 ± 120	15.86	1213-910 BC	1322-814 BC
123147	5L-1 54-55	-25	0.6495	3470 ± 70	17.04	1885-1733 BC	1972-1615 BC
123219	6L-1 31-32	-25	0.3527	8370 ± 320	17.81	7761-7023 BC	8230-6632 BC
123148	7L-1 42-43	-25	0.3178	9210 ± 100	18.92	8492-8304 BC	8651-8255 BC
123149	8L-1 77-78	-25	0.3135	9320 ± 70	20.27	8650-8468 BC	8748-8342 BC
123150	9L-1 22-23	-25	0.2993	9690 ± 400	20.72	9772-8547 BC	10452-8179 BC
123151	9L-1 27-28	-25	0.2533	11030 ± 130	20.77	11118-10928 BC	11237-10872 BC
NZA23878	basal date	-30.2	0.2520	11017 ± 45	21	11008-10944 BC	11109-10919 BC

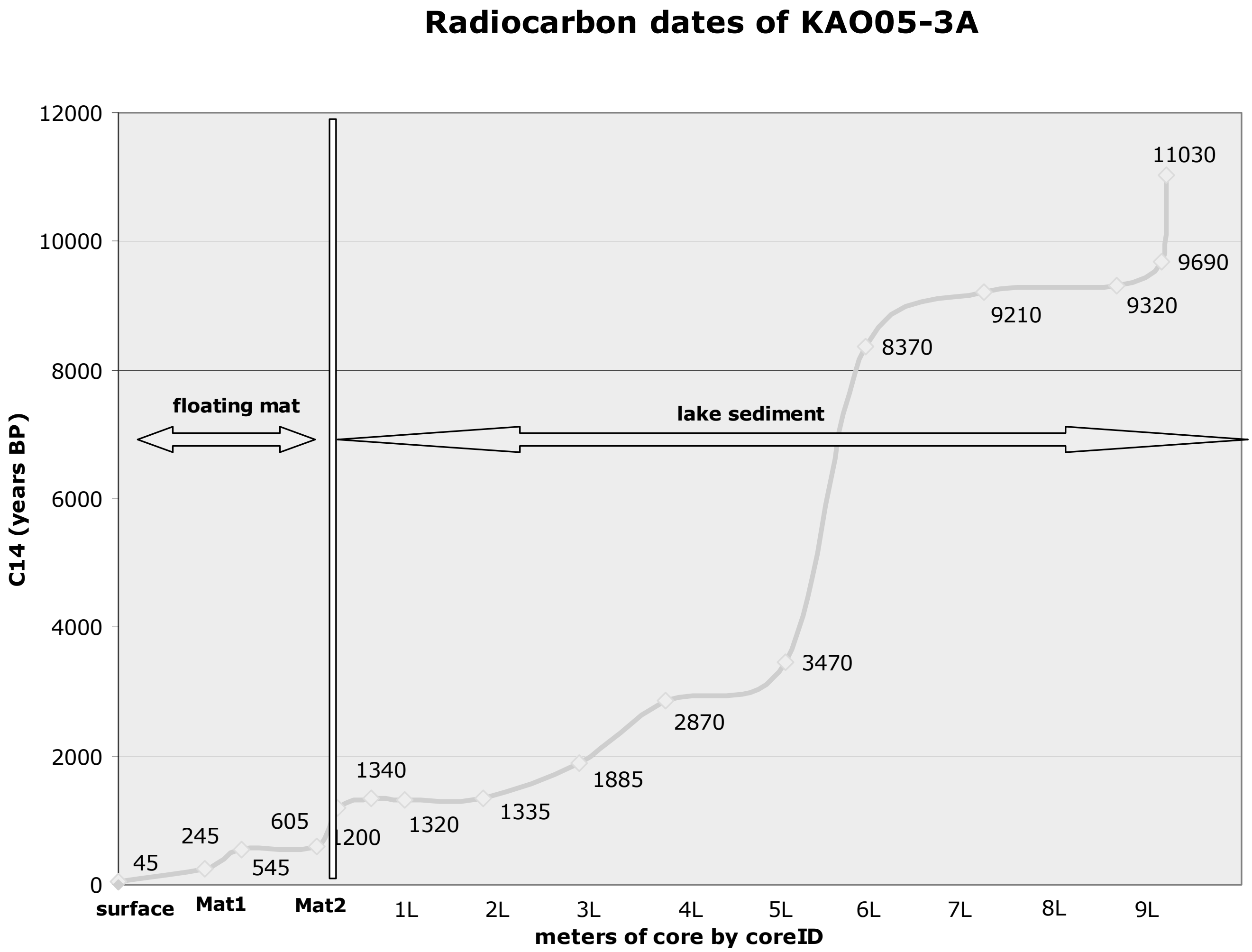

Figure 4. ^{14}C dates of both the mat and lake sediment core KAO05-3A.

that John Flenley began with plant types which prefer climate differences.

Two indicators that we looked for in the lake were calcium carbonates, or *ostracoda* and diatoms; both were sparse to non-existent. The decomposing plants leave a black tea with hardly any carbonate in its waters, leaving only plants as the key.

Scirpus

Scirpus was the key to obtaining proper radiocarbon dates, and it also holds the key to understanding the relative humidity of the lake's microclimate, the hydrology and soil development, as well as the exchange with atmospheric CO_2. In carbonate-deficient lakes like Rano Kau, organic matter and cellulose will prove to be useful archives.

The chemical structure of cellulose contains carbon, hydrogen and oxygen, each a potential collection of isotopic information. While the ratio of carbon, oxygen and carbon-bound hydrogen isotopes is "locked-in" with death of the cellulose-synthesizing organism, oxygen-bound hydrogen are exchangeable.

The new and exciting portion of my research is the direct testing of moisture. Plants tell us when the climate was cool and moist by producing those plants that thrive in that environment, while a warm and dry climate allows other species to grow. The aquatic plants, *Scirpus* and *Polygonum*, floating on the lake, are the keys that we are looking to for moisture changes, evaporation, transpiration, rainfall, and temperature changes in the lake. These are the vascular systems and provide the cellulose that can be used to trace lake water history.

At present, Brent Wolfe, Associate Professor and NSERC Northern Research Chair in the Dept. of Geography and Environmental Studies at Wilfrid Laurier University, is leading the analysis of the samples of KAO05-3A and soon we will have a paleo-climate profile of Rapa Nui going back to the end of the last glacial period; it will uncover what past climate conditions were like.

Patterns of drought, rainfall, and water balance will enlighten the type of environmental conditions that were changing and impacting the forests, the plants, the lakes and the humans who were living here.

CONCLUSIONS

With the current information we have collected on KAO05-3A, we know that, sometime around the AD 600s, something drastic changed in the island's forests and soil. Sediment in the lake shows that almost two meters of soil eroded quite rapidly, in about 40 years time. Nowhere else in the KAO05-3A core profile has this rate of sedimentation occurred so fast.

Trends over the past 12,000 years show that a common 0.1 cm per year sedimentation rate has occurred in this lake, while between 8370 BP and 3470 BP, it was very dry and had a 0.01cm rate per year. Flenley has been conducting new dating and analysis on his previous KAO 02 core, also taken from this lake, and his dates are aligning to support what I have found thus far in KAO 03. He has profiled more pollen studies and is uncovering more details that show a distinct mark of charcoal increase and change in aquatic plant abundance at around the same time period as the sedimentation rate that I found.

As for the plants, the carbon/nitrogen ratios are good for the lake sediment samples and show evaporation trends. Once the isotope analysis is complete, we can compare the coral cores that Rob Dunbar's group obtained, and compare changes in the ocean isotopes to the lake water isotopes in order to tease out events that happened on the island, and begin to finally correlate moisture changes with forest changes and, perhaps there will be more amazing surprises to come.

Candace Gossen is a PhD candidate in Environmental Science at Portland State University in Portland, Oregon. More information can be found on her webpage at www.solar783.com.

FURTHER READING

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