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A poster session paper summary

THE PALEOECOLOGY OF RANO KAO AND THE ENVIRONMENTAL DYNAMICS ON RAPA NUI -THE LAST 15,000 YEARS

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Summary

Recent Research at Ava Ranga Uka includes the coring of four water sites along an 8km long collapsed lava tube to find out if significant carbon and nitrogen relationships to drought and rainfall fluctuations could be found on the terrestrial landscape. In 2005 we conducted the first paleoecological studies using oxygen isotopes were conducted in Rano Kao and the core KAO3 produced 15,000 years of climate change cycles, periodic events and ecological changes in the forest and plant ecosystem. With this recent research we asked if the periodic water flow in Ava Ranga Uka could produce results similar to the lake water changes we discovered in Rano Kao.

In 2014, four half-meter cores were taken from water pools and waterfalls near to a newly discovered water fertility site at Henua Nua Mea. Within this site were the cultural artifacts of deliberate palm tree planting within man-made water channels. Connecting the paleoecological data from Rano Kao with the carbon/nitrogen results of Ava Ranga Uka, we begin to find patterns of drought and rainfall. When radiocarbon dates are available we may find that these climate events are related to this significant cultural site and perhaps to a cyclical climate event due to return in 2027.

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Intro

The following paper originally began as a poster session at the 9th International Conference on Easter Island and the Pacific introducing the experimental research at Ava Ranga Uka A Toroke Hau, Rapa Nui conducted in 2014. This research however is part of a long and continuing paleoecological study that began at Rano Kao in 2005. We will begin with our most recent research and tie into the previous findings laying out 15,000 years of paleoecological discovery that has helped shape a new story for Rapa Nui. The cultural dynamics expressed as moments within punctuated environmental cycles is present in the timeline and the methods of environmental archaeology is helping to reconstruct the relationships that the Rapa Nui people have had with their environment and the apparent adaptation within these ecological changes.

Recent Research

In 2014, the spring field work included working near the site, Ahu Henua Nua Mea at Ava Ranga Uka with the German Archaeological Institute. It was a wet season and there were many waterfalls and pools of water. Terevaka is what I call the rainmaker and it is from there that water, VAI, travels down this ancient collapsed lava tube running into Rano Aroi, through Eucalyptus forests, alongside Henua Nua Mea, over grassy waterfalls, and pools until it finally settles 8 kilometers later into a wetland area to the north of Opipiri. I decided to do some exploratory work to see if the water collecting in these pools would pick up periodic Carbon/Nitrogen influx of rainfall and drought as I had found in the oxygen isotopes in the lake sediment of Rano Kao. Four sites were picked, one at the well-formed lava tube near the hibiscus bushes south of Rano Aroi, a second core taken in a water pool north of Henua Nua Mea and another down the 20m waterfall to the south of this same site. The final sample was retrieved from a stone basin/well at Opipiri near the southern coast. (Figure 1)

Small 5cm diameter plastic tubes were purchased at the hardware store at Hanga Roa and cut to half-meter lengths. Unknowing how deep the sediment would be at each of these locations, the wettest spots were chosen for ease of driving the tube into the earth and to acquire the largest deposits. Using a rubber mallet, each tube was driven until rock stopped any further vertical drive. (Figure 2)

The cores were then taken back to LacCore at the University of Minnesota where the previous Rano Kao cores are stored. They were processed just as all lake sediment cores are: split, scanned, photographed, sampled with smear slides, and then sub-sampled at 4-5cm intervals for pollen and isotope analysis.

The isotope analysis was conducted at Wilfrid Laurier University, Waterloo, Ontario while the pollen and core research I analyzed at the University of Minnesota, St.Paul in the Ecology Lab of Professor Emeritus Edward Cushing. Results follow below.

Previous coring of the lake Rano Kao

Oxygen Isotopes - Evidence of Climate Change

After the volcano cratered and formed Rano Kao some 300,000 years ago, this basin began to collect rainfall. Over time a lake began to form and a viable ecosystem of trees, shrubs, ferns, grass, birds, animals, insects and people thrived here. Rano Kao thrived in its own unique ecosystem separate yet connected to the island; it is a unique microclimate, deep enough (250m rim to lake) to be sheltered from the ravaging winds that frequent the island yet subject to intense solar radiation. Slowly the lake releases its moisture, evaporating and supporting its thriving plant ecology. After the lake went through its trials of drought and bogginess, a matted cover threaded with roots and stems of *polygonum* and *totora* formed (3500BP) and slowly lifted from its boggy surface (1800BP). The floating mat with depths between 2-4m became a floating peat bog also with its own unique ecosystem within the Rano Kao microclimate.

How does an ecologist discover the range of tolerance and environmental preferences between aquatic and terrestrial plants that are both inside and outside of a volcanic crater? That was a special challenge for this research as more than 20 plants discovered as fossil pollen in the core no longer exist on the island. Many of these plants were endemic and are now extinct. Being left with only the remnants and fossils in the lake sediments, they were used nonetheless to date, test and reflect upon what kind of environment they were living in.

Introduction to Cellulose Isotope Studies

Lake sediments are useful in advancing our understanding of ancient environments. Trapped within the sediment deposits are carbon and oxygen isotopes from the decaying aquatic plants that flourished in a lake system, and consequently the lake sediment cellulose can provide a record of the lake's paleohydrology. More commonly, carbonates have been used in paleolimnological investigations, but sometimes the lake does not have sedimentary carbonates, as is the case of Rano Kao. Therefore, cellulose is the best option for analyzing the history of such a lake. The main input of carbon in the oxygen isotope analysis came from the two aquatic plants *polygonum* and *totora* that grow on the lake surface. As the lake changes with rainfall input and evaporation, the lake water history is captured within the cellulose of these plants.

Analyzing carbon and oxygen isotopes in lake sediments is a recent science, first tested by Wolfe, Edwards and McAndrews in 1989 to investigate the Holocene paleohydrology of a lake in southern Ontario, Canada (Wolfe, 2001). For lakes that are carbonate-free in their sedimentary process, such as a volcanic crater lake of basalt, aquatic plants that thrive on the lake water offer another option for analysis of carbon and oxygen isotopes. Wolfe, from Wilfrid Laurier University in Waterloo, Ontario wrote that "Lake sediment cellulose has been used as an archive of paleoenvironmental information in diverse geographic and ecoclimatic settings" (2001, p.373). He listed places around the world where cellulose has been used to determine lake paleohydrology, including the Great Lakes of North America, Eastern Africa, the Arctic and Subarctic, subtropical Andes, and the ancient glacial lake Agassiz (2001). Rano Kao was the first lake in the South Pacific where this was attempted, and KAO3 produced excellent results.

With a floating mat of two aquatic plants as well as algae, cyanobacteria, and other nitrogen-fixing organisms, Rano Kao provides suitable materials for this type of analysis. The lake is rich in flora that collect a signature of stable and dynamic isotopes deposited into the cellulose of their cell walls. This cellulose is primarily found in stalks, stems, trunks, and woody parts of the plant (Ott et al, 1954). In the floating mat of Rano Kao there are two aquatic plants: *totora*, a sedge with a horizontal rhizome, and *polygonum*, with a segmented hollow channeled root and rhizome plant; both are high in biomolecules and cellulose. The KAO3 core was comprised mostly of 15,000 years of decomposed detritus from these aquatic plants.

The $d^{18}O$ signal in the lake sediment cellulose reflects changes in climate, particularly rainfall cycles and patterns with distinct events occurring periodically. The signal also reflects a change in temperature, solar conditions and wind, but the isotope analysis alone cannot differentiate cause and effect; the pollen and ecology portion of this research (Figure 3), is critical to support the climate data revealed in the isotope analysis. Detailed results for the isotope record for KAO3 are discussed in the upcoming sections.

Results are in the Water

Carbon and oxygen isotope analysis of cellulose in lake sediments can be used to trace lake water changes ($d^{18}O$) by applying a cellulose-water fractionation factor between terrestrial cellulose and leaf water. This isotopic fractionation results in a Meteoric Water Line (MWL) observed between the oxygen isotope ^{18}O and deuterium ^{2}H. It is the composition of the oxygen and hydrogen isotopes that enter the lake from rainfall that define two linear relations. In 2005 the first water sample of the lake measured at

($d^{18}O$+2.57mil) and increased slightly to ($d^{18}O$+2.64) in 2008. The sample in 2014 registered near 2.0mil. The level of the lake has also dropped by 2 meters between 2008 and 2014 with no known cause. (Fig 4)

The long-term trend lines of the oxygen isotopes are shown in Figure 5 uncovering evidence of the lake responding to global climate trends, by recording drought and rainfall changes in the lake water. The oldest sample dating to 15,000 years ago captured the Last Glacial Maximum (LGM) that sharply rises from a cool dry environment with oscillations of wet periods into the hottest event of the record at 9,274BP. This trend has a very steep 3,000 year growth towards warmer and wetter into the Holocene. The second trend line from 9,274BP to current covers a 9,000 year time period. This trend line represents a negative slope towards isotope depletion, becoming cooler and drier. Over the last 2,000 years the lake has been relatively stable. The rainfall into the lake has been greater than the evaporation out of the lake with increasing evaporation over time. Cycles of cold events (637years) and hot events (719years) are noted with the next expected cold event to return in 2027AD (Figure 6).

Over time the lake Rano Kao changed with rainfall input and evaporation. These moisture changes were captured within the cellulose of the aquatic plants and are recorded in the lake water history including complete desiccation of the lake in 3500BP. Determining the island's ecological changes based upon the isotope data alone is nearly impossible. The question that remains is what happened to the terrestrial plants? Particularly, did they have the same response as the aquatic plants during drought? These subtle details are therefore indicated in the environmental tolerance of each of the plants and the context in which they were growing.

The cores taken from Ava Ranga Uka (ARU) in 2014 were an attempt to collect soil sediment that would reflect rainfall and drought. The topography of ARU (Figure 7) clearly reflects that water flows periodically here, sometimes heavy and at other times none. The question was how to compare the aquatic cellulose to terrestrial soil chemistry to gather similar and comparable information. Referring back to the original Carbon/Nitrogen content of each of the samples from the lake and from the lava tube cores, we present this information in attempting to find patterns of comparison.

Discussion

Carbon Cycling

Carbon cycling is evident in the lake Rano Kao detected in the changing cellulose carbon isotope composition ($^{13}C_{cell}$) values. The carbon-13 results have two distinct profiles in the KAO3 core reflecting the cold LGM with little carbon input from an open lake. ^{13}C declines with each cold event and increases with warming. The comparison of organic carbon (C_{org}) and nitrogen (N) percentages are useful indicators of plant growth which is what we would like to compare to the terrestrial carbon cycle of Ava Ranga Uka.

The results of KAO3 weighted C/N ratios show values ranging in the 24-63 percent area throughout the nine meters of lake sediment cores and between 30 and 80 percent in the floating mat. (figure 8) The organic carbon percentages are always greater than 50 percent and the nitrogen levels range from 0.8-2.3 percent. In comparison to the terrestrial samples at Ava Ranga Uka, the C/N ratio varied between 9.9 and 24.3 percent. Organic carbon ranged between one-tenth of a percent to 6.3 and nitrogen levels 0.14 percent to 0.38. The terrestrial samples clearly show less productivity as compared to the lake. Each of the four sample areas along Ava Ranga Uka have unique ratios of Carbon and Nitrogen input, but amongst the four they have similar patterns over time, meaning they are reacting to similar events. However each area is unique, perhaps a deeper pool would have more plant growth, and a shallow rocky waterfall less. It is advantageous to compare multiple sites along this collapsed lava tube which is a water way carrying organic matter between Terevaka and Opipiri running for 8 kilometers towards the sea and though cultural sites where water would have been significantly necessary.

A graphic summary for each sample core at Ava Ranga Uka is displayed along with the pollen counted in each sample in (Figures 9-12). The samples were high in minerals and low in pollen, however palm pollen (not modern day *Cocos nucifera*) was present although highly disturbed, some were damaged but identifiable. The total pollen counts are displayed along with the carbon and nitrogen percentages for each coring site as noted.

Summary and Conclusions

The KAO3 analysis showed that throughout the paleoecological record, a diversity of five palm species and seventeen other tree species survived in abundance and diversity. Although at times palm pollen quantities became very sparse, they did not disappear previous to or after human arrival. A decline in palm pollen appears around 550BP, during the peak of a very long (115 year) cold event which may have also caused failure of dry-land crop plants on the island. This climate event, cycling every 637 years, began in 1390AD. It caused great strain on the giant palm trees, as their success in ecological evolution lay in their unique genetic and independent lineages, but their demise was directly tied to their inability to undergo dormant periods. "These palms with inability to withstand freezing temperatures that would cause irreversible cavitation of tracheary elements." (Tomlinson, 2006) In other words, the behavior of the palm, in a structural sense, is more like an animal with a vascular system and unique DNA than a plant with a more modular construction. The palms strength lies in their ability to move water from the roots to the crown and breathe. These trees would have been important to the people of Rapa Nui and the most recent uncovering of palm root casts at Ava Ranga Uka may be evidence of the last attempt at saving them. Radiocarbon dates have not been produced yet, however knowing the rate of growth for the *Jubaea chilensis* (Figure 13) the 80cm diameter of the circular pits in the plaza indicate a tree roughly 100 years old, about the time of its first flowering.

The mat cores from 2008 uncovered more detail of the 545BP event and dated the last cold event occurring between 1390AD and 1505AD (peaking 1456AD). Knowing about this cold event has also helped to place the use of lithic mulch found in the terrace gardens in the time line around 1505AD (Gossen and Stevenson, 2005). Previous cultural findings place the cessation of the moai carving sometime in the 1500s which would have followed this cold event also. At Ahu Henua Nua Mea, the people of Rapa Nui distinctly built water channels and placed the giant palm trees within. These findings indicate the importance of these trees not only functionally but spiritually, worthy of being placed in a ritual setting.

The carbon and nitrogen samples taken from the Ava Ranga Uka cores have proved to be useful and interesting as they are responsive to terrestrial changes in rainfall and drought as well as being repositories for fossil pollen in which the extinct palm species of Rapa Nui were present in these cores (Figure 14). With permission from the people of Rapa Nui there is great story to be uncovered in the water and earth and plants, and this work is part of a long paleoecological study of the natural life on Rapa Nui.

Acknowledgements

Great thanks to CONAF especially Enrique Tuki, with whom I have worked with from the very beginning since 2002 and Ninoska Cuadros Hucke, Provincial Chief at CONAF Easter Island for permission and support. It is their program and the youth that have already begun to replant native plants at ARU, and with support and permission from the cultural heritage representatives we can collectively work together to bring the story to the world. Thank you to the elders who have shared the early stories with me and to the ancient that keep sacred the home of my friends. I am also very grateful to Burkhard Vogt and the German Archaeological Institute for inviting me to work with them in 2014 and helping to collect and fund the processing of the cores. To all of our friends that are now gone from the island, we miss you. Thank you to LacCore at the University of Minnesota who always welcome my work and cores into their labs and a deep heart felt thank you for my friend and mentor Ed Cushing who has now closed his lab

and focusing on his own flower beds. Ed taught me everything I know about fossil pollen, plants, ecology and human perseverance in finding the answers even when its hidden deep and far away.

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Figure Captions

Figure 1. Map of Ava Ranga Uka core sites 2014

Figure 2. Photo of coring procedures at ARU 2014

Figure 3. Mat 1 core from 2008, Pollen and C/N data profile

Figure 4. Lake Water History Composition 2005-2014

Figure 5. KAO3 Oxygen Isotope Trendlines and Climate Events

Figure 6. Mat 1 - Climate Events via Oxygen Isotope Data

Figure 7. Photo of Ava Ranga Uka A Toroke Hau 2014

Figure 8. Mat 1 - Carbon and Nitrogen Data

Figure 9-12. ARU cores 1-4 (pollen quantity, carbon % and Nitrogen %)

Figure 13. Jubaea chilensis photo (Chile)

Figure 14. Palm pollen in ARU cores

Figures

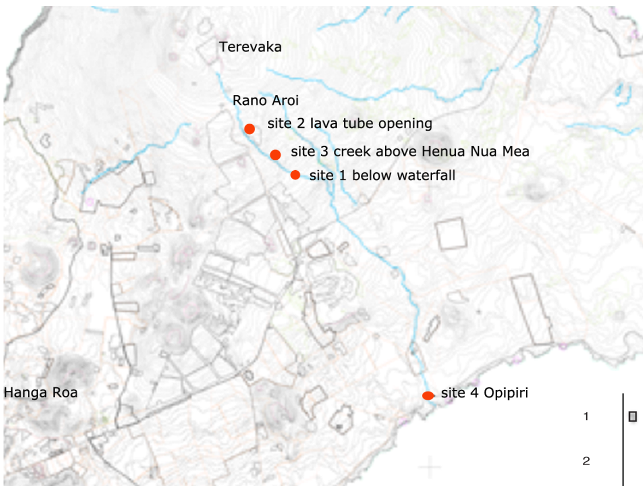


Figure 1. (Upper left) Map of Ava Ranga Uka with location of 4 coring sites.

Figure 2. (Upper right) Coring at Ava Ranga Uka (photo courtesy of Burkhard Vogt)

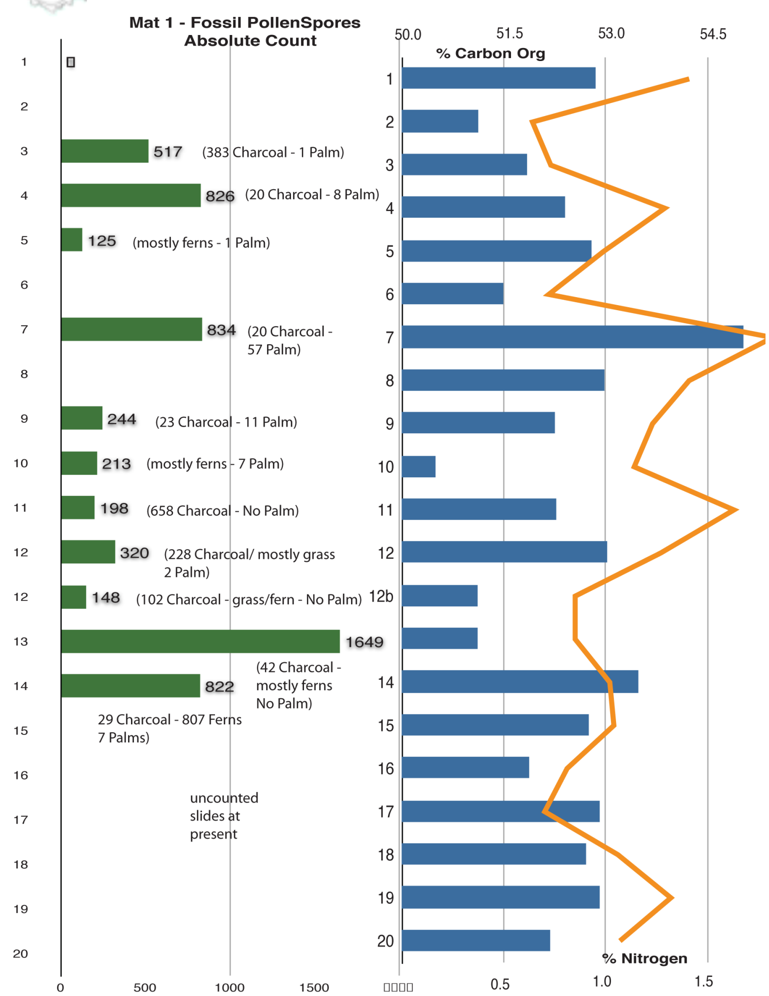
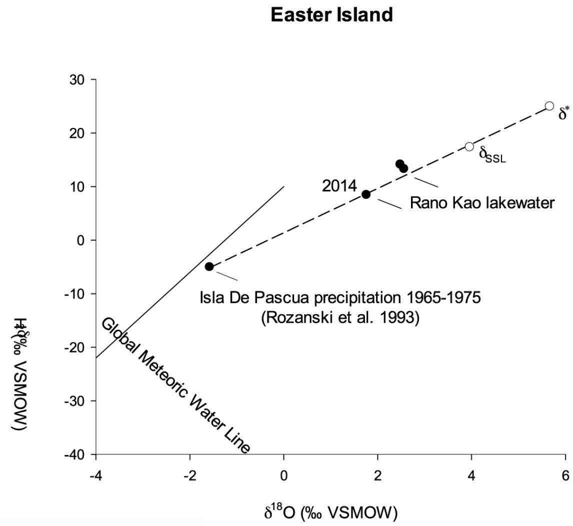


Figure 3. Rano Kao Mat 1 - Pollen, Carbon and Nitrogen results

Figure 4, Rano Kao - Lake Water Evaporation

- 2005, 2008 and 2014



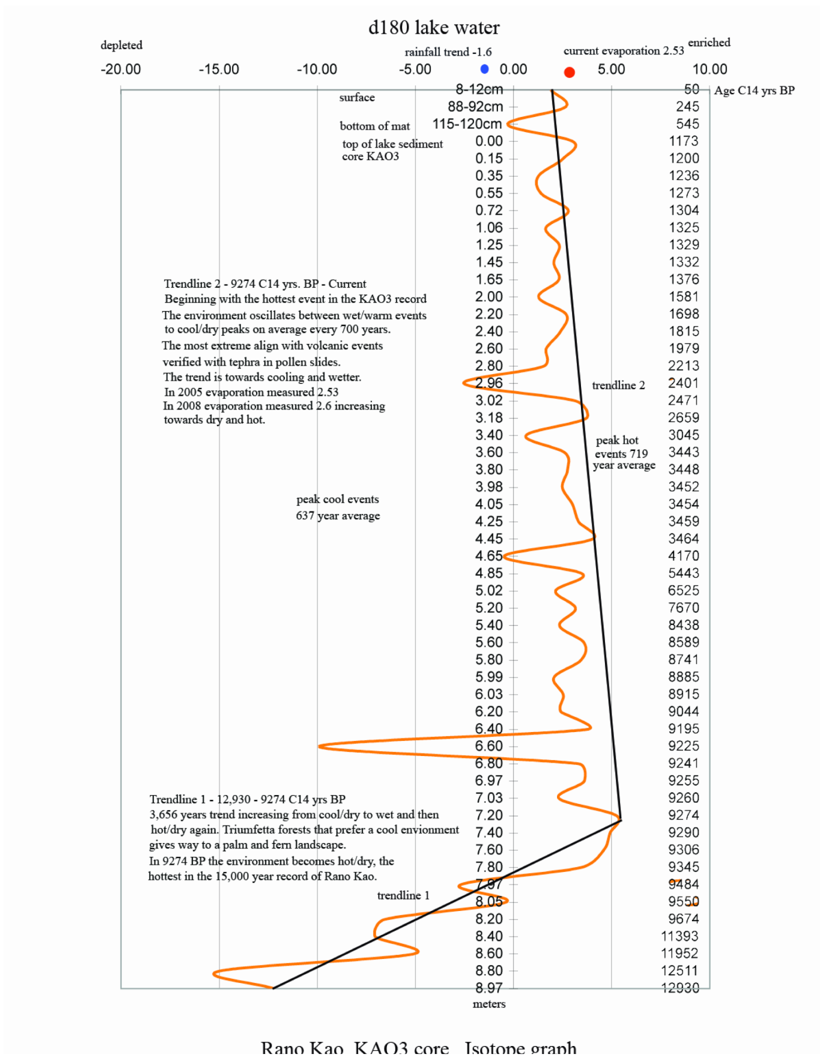


Figure 5. KAO3 d[18]O$_{lw}$ results with trend lines and climate events. This core was taken from the lake sediments beneath the water column.

Figure 6. (right) Mat 1 d18Olw results of the last 1000 years of climate cycles including the long term cold cycle every 637 years that peak in 1456AD and lasted 115 years. This core is from the floating mat above the 12 meter water column.

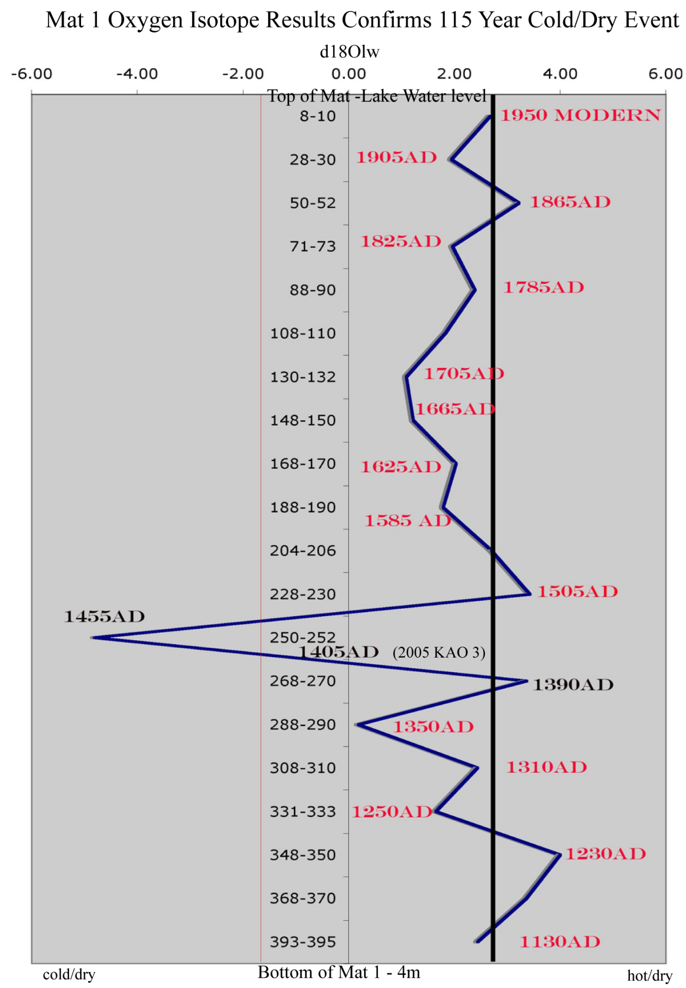


Figure 7. (below) Photo of Ava Ranga Uka watershed in collapsed lava tube. Looking south below Ahu Henua Nua Mea towards Opipiri.

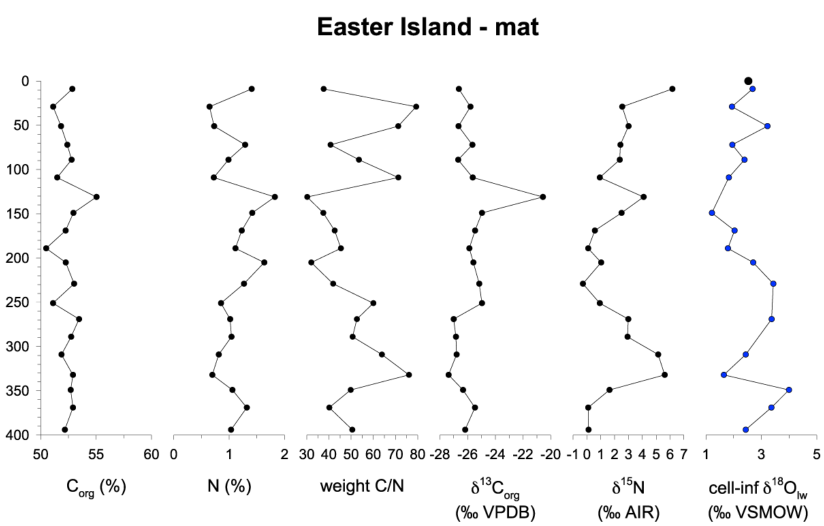
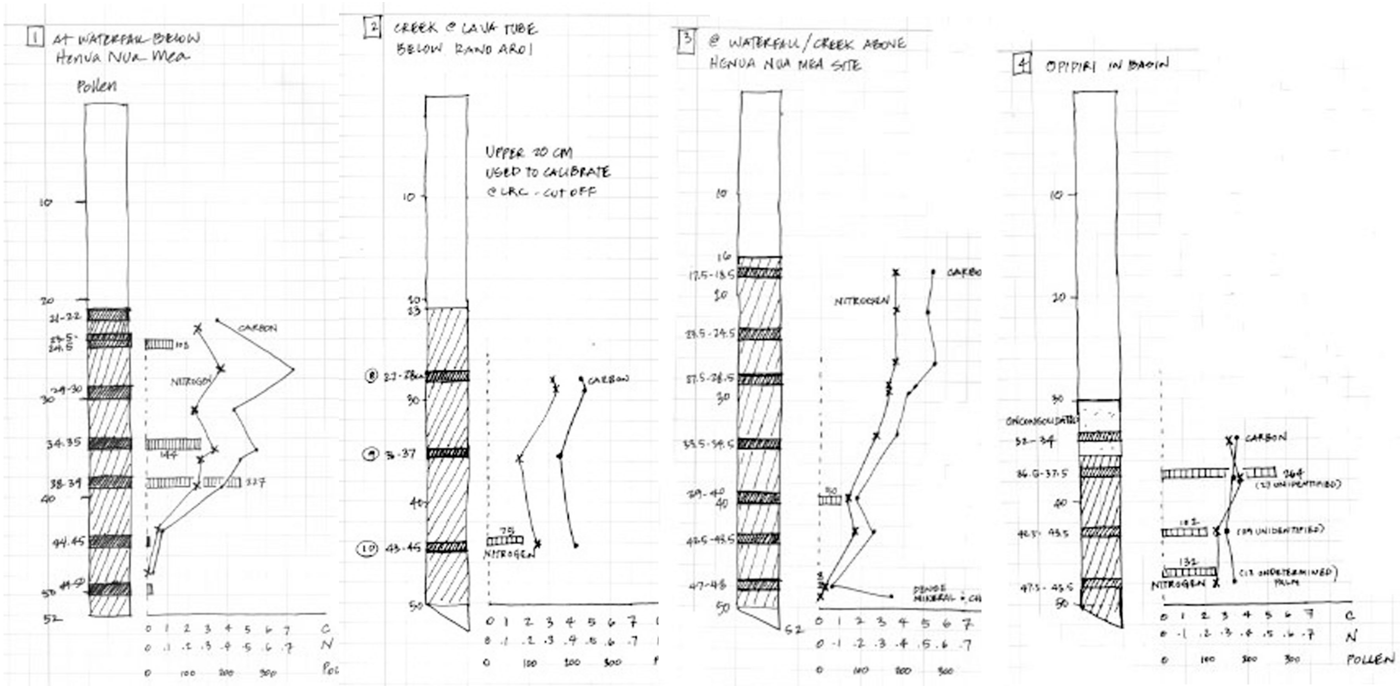


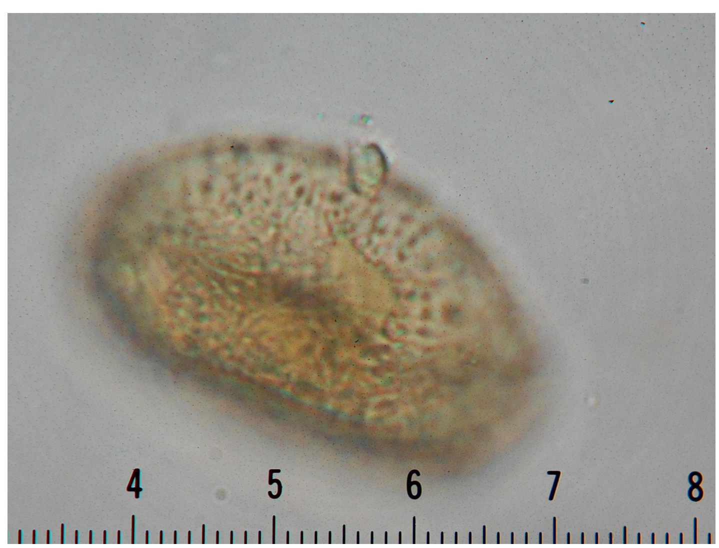
Figure 8. Mat 1 - Carbon and Nitrogen results (4meters depth from lake water surface)



Figures 9-12 ARU cores as sited on the map in Figure 1. Pollen, C/N results.

Figure 13 (left) *Jubaea chilensis* at the Museo Nacional de Historia Natural in Santiago, Chile. Approximately age 180 years old.

Figure 14. Fossil pollen of extinct palm identified in the Ava Ranga Uka cores.



Sumario

Dinámicas culturales y ambientales en la Rapa Nui -el últimos 15.000 años

La investigación reciente en Ava Ranga Uka incluye la extracción de muestras de cuatro sitios de agua a lo largo de un largo tubo de lava se derrumbó 8 km de averiguar si significativa de carbono y las relaciones a la sequía y las precipitaciones fluctuaciones de nitrógeno se podían encontrar en el paisaje terrestre. En 2005 llevamos a cabo los primeros estudios paleoecológicos utilizando isótopos de oxígeno en Rano Kao y el núcleo KAO3 produjeron 15.000 años de ciclos de cambio climático, eventos periódicos y los cambios ecológicos en el ecosistema forestal y vegetal. Con esta investigación reciente nos preguntamos si el flujo periódico de agua en Ava Ranga Uka podría producir resultados similares a los cambios en el agua del lago que descubrimos en Rano Kao.

En 2014, se tomaron cuatro núcleos de medio metro de agua de las piscinas y cascadas cerca de un sitio de la fertilidad agua recién descubierto en Henua Nua Mea. Dentro de este sitio eran los artefactos culturales de la plantación de árboles de palma deliberada dentro de los canales de agua artificiales. Conexión de los datos paleoecológicos de Rano Kao con los resultados de carbono / nitrógeno de Ava Ranga Uka, empezamos a encontrar patrones de sequía y precipitaciones. Cuando las fechas de radiocarbono están disponibles, podemos encontrar que estos eventos climáticos están relacionados con este importante sitio cultural y quizás con un evento climático cíclico que regresara en 2027.