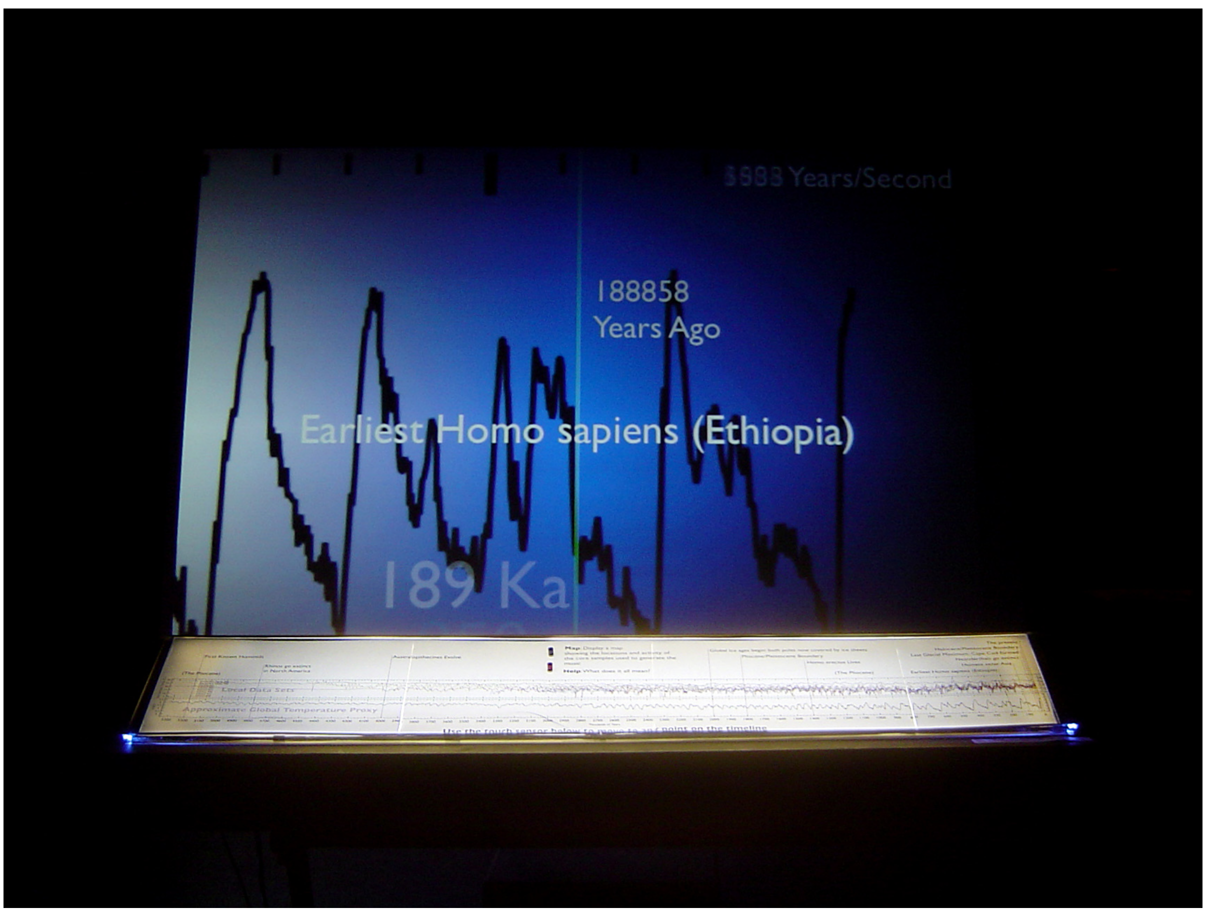
Climate Controlled

An interactive sonic and visual installation based on 5.2 million years of climate change from the geologic record

by Arvid Tomayko-Peters

An undergraduate honors thesis
Brown University Department of Music
2007



Climate Controlled

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Arvid Tomayko-Peters
Concentrating in Computer Music and Multimedia
Brown University Music Dept.

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Arvid Tomayko-Peters
September 28, 2006

Introduction

I would like to propose a senior thesis project bringing together geology and music in a creative fashion. In this project geologic data from Earth systems will be mapped to sound generation parameters to create 'Geophonic Music[1]'. This will bring together both of my concentrations as an undergrad at Brown – Computer Music and Multimedia, and Geology. This project will take the shape of an interactive sonic installation based on a set of geological data with an optional performance element.

Why Geology and Music?

Geologic records preserved in the rocks, such as deep ocean sediment or a section of shale, record changes in the lithosphere and environment of the Earth over time. In geology, if you find yourself measuring vertical distance, you are most likely measuring time. Similarly, music is created from events over time. Speeding up geologic time from 100,000 years to, for instance, 100 seconds allows changes in data values to be mapped to human-listenable musical parameters. Similarly, speeding up data even farther allows data to be mapped to sound waves of audible frequency! Since earth processes proceed in many complex cycles and natural feedback loops, patterns should emerge in geophonic music, creating not only an edifying listening experience, but also possibly something that makes sense scientifically.

For any geologic record a number of different sets of data can be taken. For instance from a deep ocean core you can systematically measure isotopic abundances of Oxygen and Carbon, color, magnetic susceptibility and density, among other properties. Also, to get a bigger picture of what is happening, you can take data in many geographic locations. These different data types may correspond to instruments in music, and different geographical locations might corresponding to sonic spatialization. In any case, connections can be drawn and music can tell the story of the earth though time in a condensed format.

Project Realization

This project will take the form of an interactive installation in which sound created or mediated by geologic data is geographically spatialized. The listener will move through the space hearing geologic data influence various characteristics of the sound and hopefully pick out patterns that have scientific significance. An interactive component will allow listeners to affect the sound the installation makes by possibly choosing the set of data to use, or by influencing the time period portrayed, the speed of playback of the

1 'Geophonics' is a term coined by Alessandro Montanouri, an Italian geologist and musician and Gabriele Rossetti, an Italian musician and IT expert, both of whom I worked with this summer creating Maestro Frankenstein, a complete re-write of their previous software using its core idea of mapping geologic data to music but creating a more user-friendly and flexible application running on both Macintosh and Windows platforms.

data, and the mapping of the data to sonic parameters. This could be done either through the use of a computer terminal present in the space that the listener(s) interact with in a semi-traditional human-computer interface, or through the use of sensors. The best and most effective method of interaction is not yet known, but interaction will be explored though experiments over the course of the project. One possible idea is allowing listeners to take a virtual journey through space and/or time with entertaining graphics and a simple interface that would encourage people to 'play' with the installation. The interaction apparatus should also have the capability to be harnessed by a performer who knows the system well (probably myself) and used in a more performative manner.

One possible data set to use for this installation is deep ocean cores. These cores, drilled at various locations in the Atlantic and Pacific Oceans, give insight into climate change and ocean behavior hundreds of thousands of years into the past. The sediment that builds up is largely the remains of tiny planktonic organisms, some of whom make their shells out of Calcium Carbonate and others Silica. It is through the effect of climate on these organisms, along with other local factors, that we are able to see these cycles preserved in the rock record. There are many parameters that can be measured in such cores. Last year I took Geology 124 with Professor Tim Herbert in which we completed three large, data intense projects using deep ocean cores. I know how to work with this data, what it means (mostly) and where I can get access to it, making it an excellent choice to base a project on. However, other sources of data such as ice cores, tidal cycles, spatial magnetic banding of oceanic crust, volcanic history and models of geochemical fractional crystallization, partial melting and phase equilibria are not to be ruled out as geophonic data.

Some possible parameters that geologic data could be mapped to are:

- Pitch
- Amplitude
- Filter frequencies
- Modulation
- Sound waves created from scaled data
- Polyphony
- Rhythms
- Event Density

Previous Investigation

This summer I worked for a month creating a user-friendly software program called Maestro Frankenstein which maps time-series data to musical notes. 'Scores' can be interpreted by a synthesizer or printed to be preformed by a human musician. My research and experience with writing this software has given me tools and insights into creating geophonic music, as well as shown me its challenges in both the realm of programming and that of the relevance of the musical results. The simple mapping actions of the software I have created serve as a starting point for thinking about geophonic music and a way to get others playing with the data-as-music concept easily.

However the model in which is functions is limited and does not satisfy my conceptual or aesthetic desires for geophonic music. This project will involve expanding the type and sophistication of mappings of data to sound, introducing realtime interaction and also increasing the scientific relevance of the music produced.

The Maestro Frankenstein program will continue to be maintained and used as a sort of 'outreach' component of the project, allowing anyone with access to time-series data and a computer to creating music from that data. It will also serve as a quick and predictable tool for me to use in composition as well as a programming model for realtime algorithms and modules to be used in the final project incarnation.

End Product

The final product of this project will be an interactive installation/performance that will be software driven. The software as well as any 'scores' for setup or performance and the geologic data used will be turned in. Documentation of the installation/performance will consist of video and audio recording and still images.

Timeline

1. October 1, 2006 – Experiments with mapping geologic data to produce sound well underway. Main body of geologic data to be used decided upon.
2. November 15, 2006 – Experiments with realtime mapping changing and rudimentary interaction well underway.
3. December 1, 2006 – Basic Data mapping to create sound and basic interaction functioning and making noise that makes sense.
4. December 8, 2006 – Project Draft: Basic performance software system completed, Data mapping established, tests relating to spatilization and aural experience completed, Maestro Frankenstein Program complete and freely available on the Internet for both Macintosh and PC.
5. January 2007 – Work on interaction and honing mapping algorithms over winter recess. Develop ideas for possible performance element.
6. April 2, 2007 – Complete Draft: Working installation that facilitates listener interaction, testing of listener interaction and performance elements complete.
7. April 2 – 10, 2007 – Concert/Installation, preceded by setup and testing in final space.

Climate Controlled

An Honors Thesis Project by
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Computer Music and Multimedia
Brown University Music Dept.

Project Advisor:
Butch Rovan

Project Conclusion

April 24, 2007

Introduction

Climate Controlled is an interactive sonic and video installation that brings together the worlds of geology and experimental music. The installation generates sound from geologic climate data that spans the last 5.2 million years of Earth's history. This installation was open March 19 – 22 in the Upstairs Space at Brown's Production Workshop.

Why Geology and Music?

Geologic records preserved in the rocks, such as deep ocean sediments or a section of shale, record changes in the lithosphere and environment of the Earth over time. In geology, if you find yourself measuring vertical distance, you are most likely measuring time. In this way, geology is all about time. Similarly, music is created from events over time. Speeding up a portion of geologic time from 5,000,000 years, for instance, to 5 minutes allows changes in data to be mapped to human-listenable musical parameters. Similarly, speeding up data even farther allows for periodic data to be interpreted as sound waves of audible frequency. Since earth processes proceed in many complex cycles and natural feedback loops, patterns should emerge in geophonic music, creating not only an edifying listening experience, but also possibly something that makes sense scientifically.

For any geologic record a number of different sets of data can be used in the creation of music. For instance from a deep ocean core one can systematically measure isotopic abundances of oxygen and carbon, color, magnetic susceptibility and density, among other properties. To get a bigger picture of what is happening, one can take data from many geographic locations. These different data sets can correspond to synthesis parameters for sound, and differing geographical locations can correspond to sonic spatialization. In any case, connections can be drawn and music can tell the story of the earth though time in a condensed format.

Geophonic music also is a way to tie together the short, enjoyable and human-understandable time of music with the inconceivably huge expanse of geologic deep time. The Earth is 4.5 billion years old. *Climate Controlled* spans only 1/1000 of that time, but that is still a duration that we cannot fathom. Through music I hope to bring the Earth's processes onto a human timescale. Music is a visceral experience and can bring home the complexity, interconnectedness and periodicity of the geologic record and the processes that have shaped and continue to shape our planet.

The Installation

The sound of the Earth's climate over the last 5.2 million years is played through 8 speakers, each of which represents a deep-ocean core that was drilled to study climate change. The different types of data from the core samples, such as $CaCO_3$ content, reflectance, density and sedimentation rate act as control parameters for synthesis, determining the sound of the piece at any given time. Sound is synthesized in realtime as visitors interact with the piece.

Projected visuals of data plots and computer-controlled room lighting respond to the data playback. Visitors see projected in front of them a large plot of global ice volume that moves with the piece's time. Its background color changes between red (warm) and blue (cold) depending on the average global temperature at that time, outlining the ice ages and warm periods. Visitors can press a button to display a dynamic map of core geographic positions and activity, giving the visitor a sense of geography. There is also a similar page that visitors can trigger that gives a very basic textual explanation of the installation and information on the projected display.

Visitors can interact with *Climate Controlled* by controlling the piece's movement through time using a 5 ft long touch-sensitive timeline. The timeline interface tracks the motion of the visitor's finger and uses that motion to determine the speed and direction at which the piece will travel through time. The timeline is displayed on a backlit console in the center of the room, in front of the projection. When the visitor touches it to move to a certain date, both the visuals and the music move immediately to that date and track the motion of the visitor's gesture as it moves over the touch-sensitive surface.

Informational posters hang above each speaker. These describe the corresponding core sample's geographic location and data types and provide a graphical representation of the dataset. Several posters also display information about deep ocean cores and the musical mapping of geologic data used in the piece. Posters are suspended from the ceiling with thread and backlit.

The sound and video synthesis, lighting control and interpretation of the interactive controller interface is done using custom software developed in MaxMSP and Quartz Composer on a Mac.

The timescale used in the installation – from 0 to 5.2 million years ago – is the timescale over which we have the best data about major climate variations. The "ice ages" are all contained in this interval. It also nicely frames human evolution, with the first hominids appearing at about 5 million years ago and *Homo sapiens* appearing about 195 thousand years ago. Data points in the data sets I am using are spaced about 1000 years apart, so *Climate Controlled* does not document the current trend of human-induced global warming. However, it does give an illustration of how our climate system functions – the same climate system that we are now perturbing with profuse CO_2 emissions.

Dates in human evolution, along with other significant biologic and geologic dates are displayed in text on the projection as they are reached in the installation's time. This helps to tie the visitor's frame of reference into anything they might know about other fields in which developments are taking place during this time period, and to relate geologic time to other time scales, putting the music in context.

Suggestions for Further Work and Research

There are several criterion by which I believe *Climate Controlled* should be evaluated: its artistic merit, its scientific accuracy and completeness, and its ability to communicate some sort of scientifically significant information to the visitor that is coherent and beyond what the visitor could experience through traditional media. This type of geological knowledge is usually communicated using words and graphics, but sound could be a new language of exploration of natural phenomena.

I feel I was about 20% successful in making Climate Controlled be something that is scientifically significant. Small changes in the data are apparent, but not necessarily coherent, due to the variability of the data and problems in its interpretation, and to the way the data is mapped to musical parameters. One can hear the major, overarching climate shifts when the sound is combined with the visual cues. Without the visuals, however, its often difficult to figure out what is going on geologically.

More work is needed to create a more effective sonic presentation of the data that is independently coherent. More careful musical mapping of data and exploration of more datasets would be a place to start. However, I feel that Climate Controlled is an effective and artistically valid step in this direction.

Documentation

Documentation of the *Climate Controlled* installation is presented as follows:

- Technical Description and Interface Design
- Photographs
- Diagram of the installation layout
- Small format prints of the posters that are displayed in the space
- Video DVD with two videos, and a slideshow
- Audio/Data CD with recordings of the installation, an electronic copy of this written documentation and the *Climate Controlled* software source

Climate Controlled: Interface Design and Technical Notes

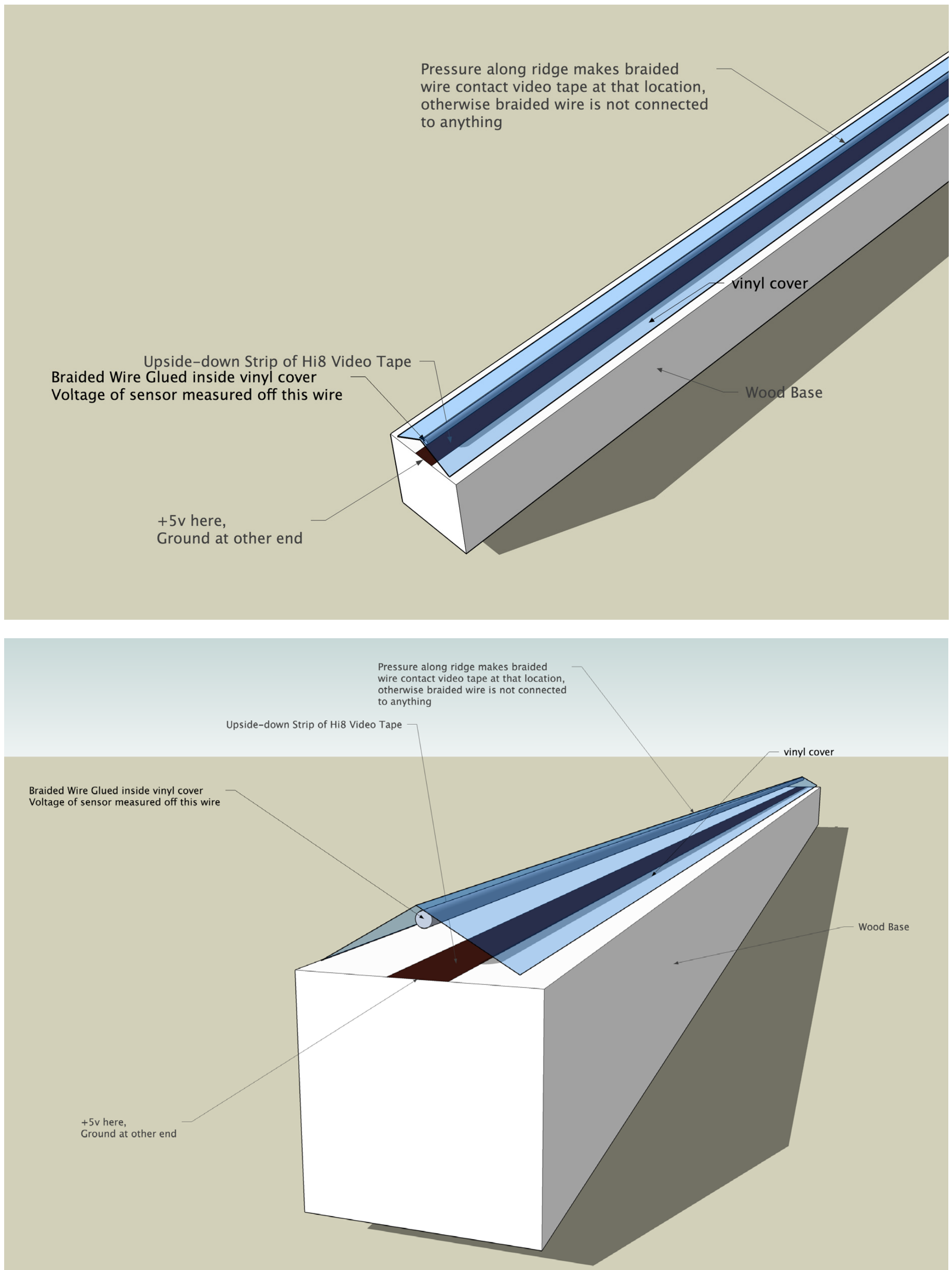
Arvid Tomayko-Peters

Interface for Visitor Interaction

Visitors to Climate Controlled interact with the installation using a 60” long touch - sensitive timeline interface similar to a large keyboard ribbon controller. By pressing his or her finger at any point on the controller, the visitor can travel to that point in time in the geologic record. When the finger is removed, the installation continues moving at the speed and direction of the last touch.

The timeline controller operates as a large potentiometer. A wire in the vinyl covering makes contact at some position along a resistive strip when pressed and a voltage is sent to a microcontroller which interprets it as a 10-bit number (0-1023) and sends it to the computer running the installation. The timeline controller was actually split in half and built as two separate potentiometers to get double the resolution (2048 possible states instead of 1024) to give the user finer control over time.

The ‘wiper’ of the potentiometer is the braided shielding of an audio cable contact-cemented to the underside of the vinyl cover. The resistive strip is the backside of Sony Hi8 video tape, double-stick taped to a wooden base. One end of each section of the video tape was connected to ground, the other to +5v.



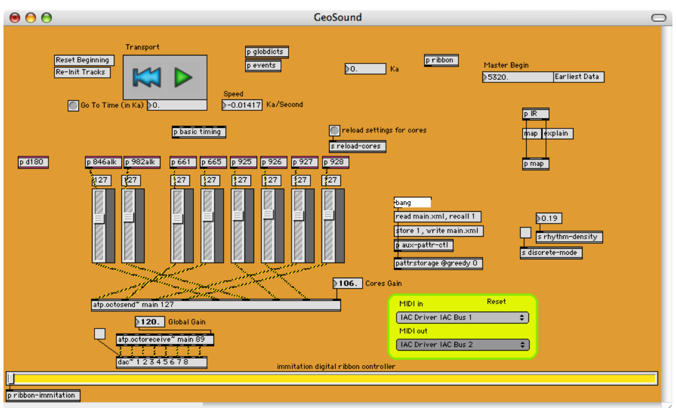
1. Illustrations of one section of the controller

Software

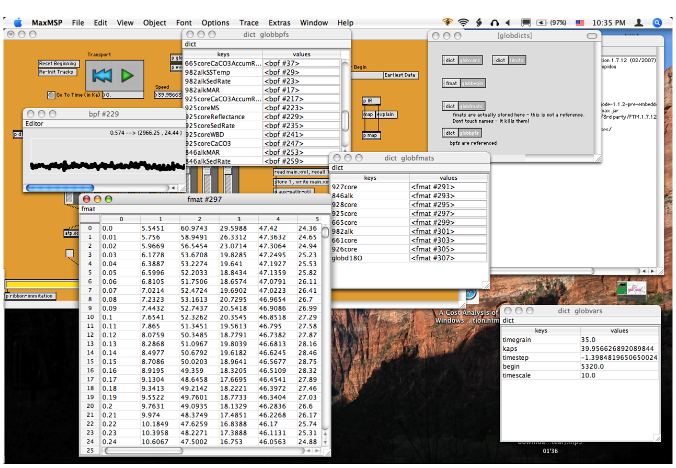
The sound and visuals of Climate Controlled are created in realtime using custom software developed in the Max/MSP environment and Quartz Composer. A Max/MSP patch stores and interprets the climate data, takes and conditions user input from the timeline controller and buttons via MIDI, controls movement through time, synthesizes sound for the 8 speakers, sends out MIDI control to a LanBox to control the lighting in the space via DMX, and sends MIDI on an internal bus to to control a patch in Quartz Composer, where the projected visuals are rendered using OpenGL.

Realtime storage, processing and retrieval of geologic data in Max/MSP is accomplished using the FTM set of externals from IRCAM which allow for the easy manipulation of large amounts of data within Max.

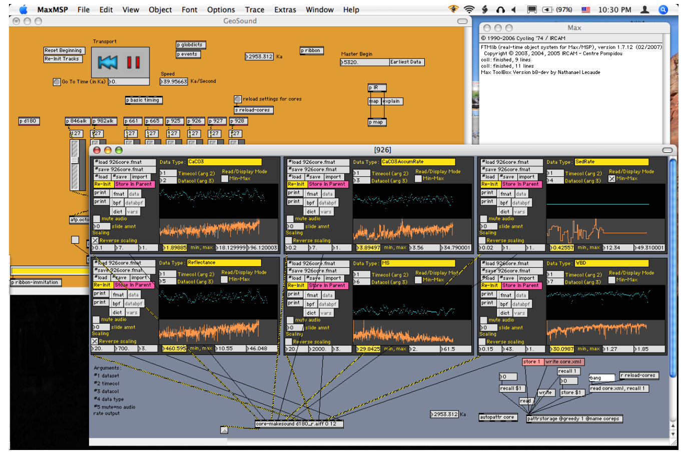
The patch has a deceptively simple main interface:



Under the hood is a hierarchical and dynamic data storage system with a spreadsheet-like GUI provided by FTM:

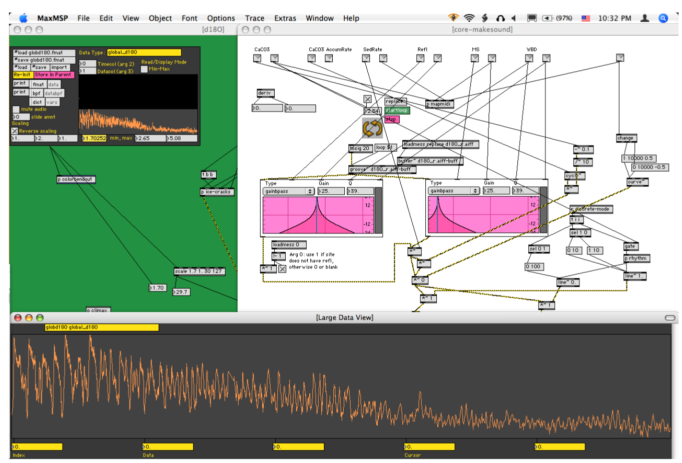


Each core's data is displayed and accessed via a modular system. The following window is the data for site 925:



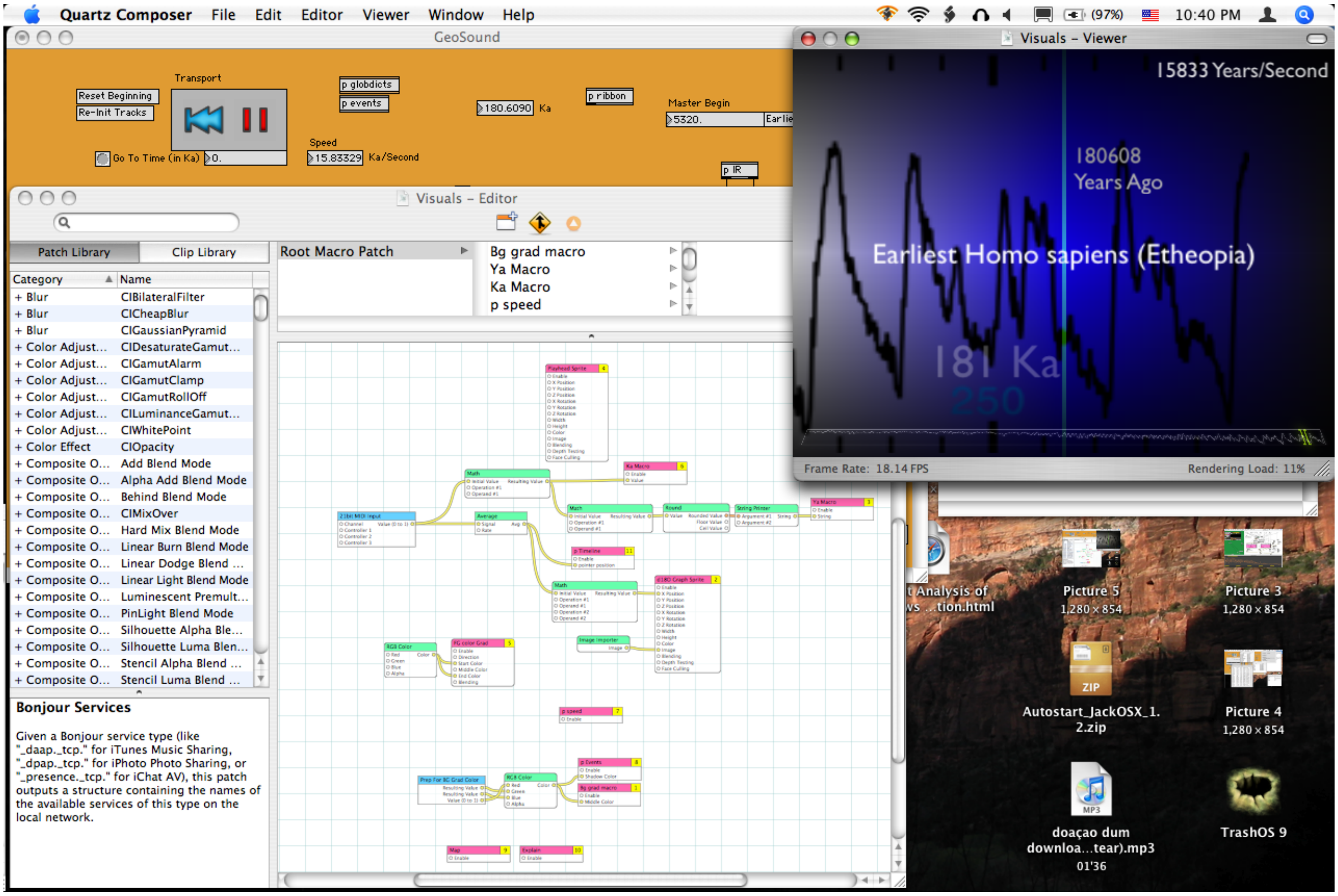
There are 49 data recall and scaling modules in total, 6 of which are shown above, each representing a different property of the 925 deep-sea sediment core. All settings are saved to a master XML settings file.

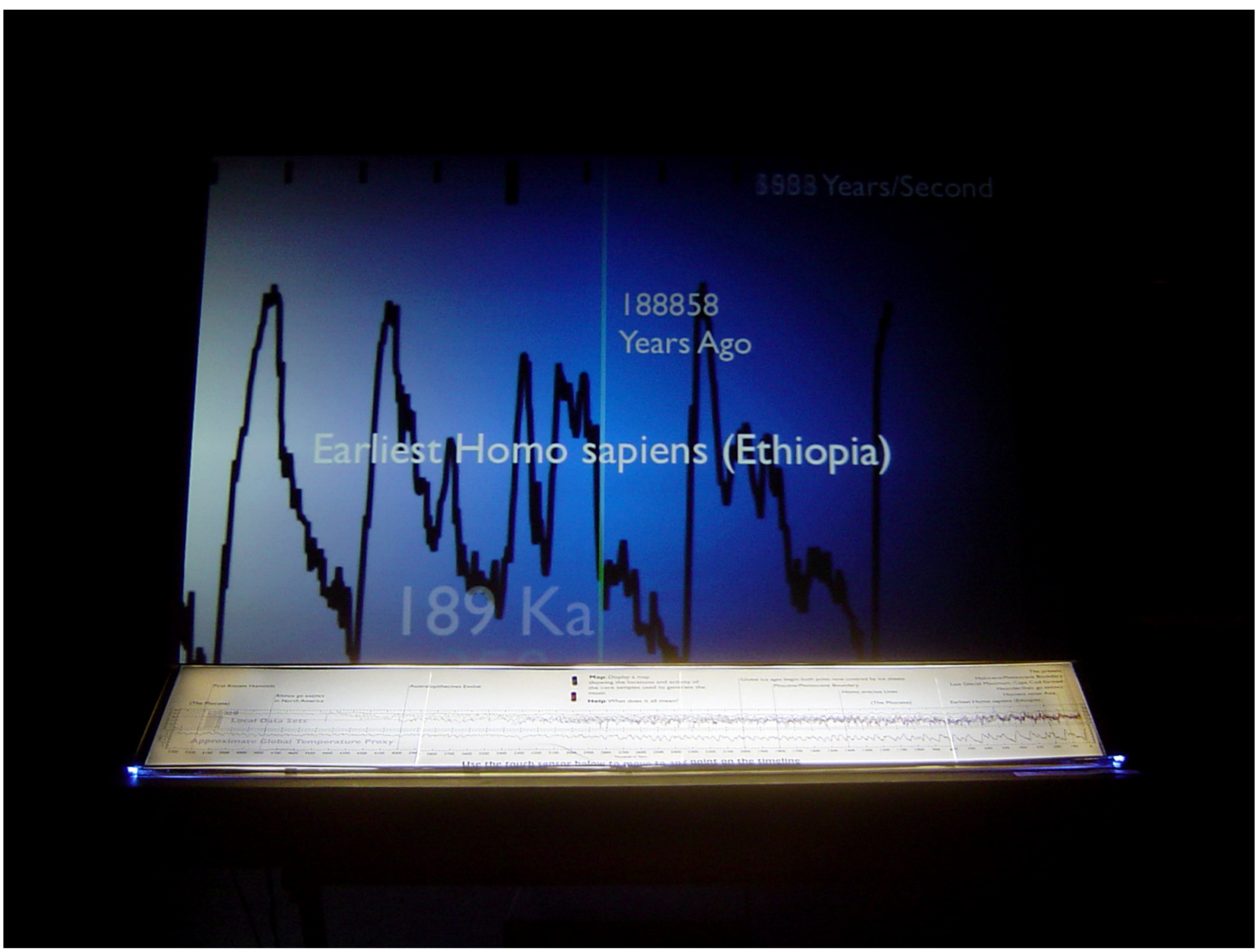
Each module can be clicked to display a larger plot (as below with global δ18O). The screenshot below also shows one of the 8 sound synthesis engines:

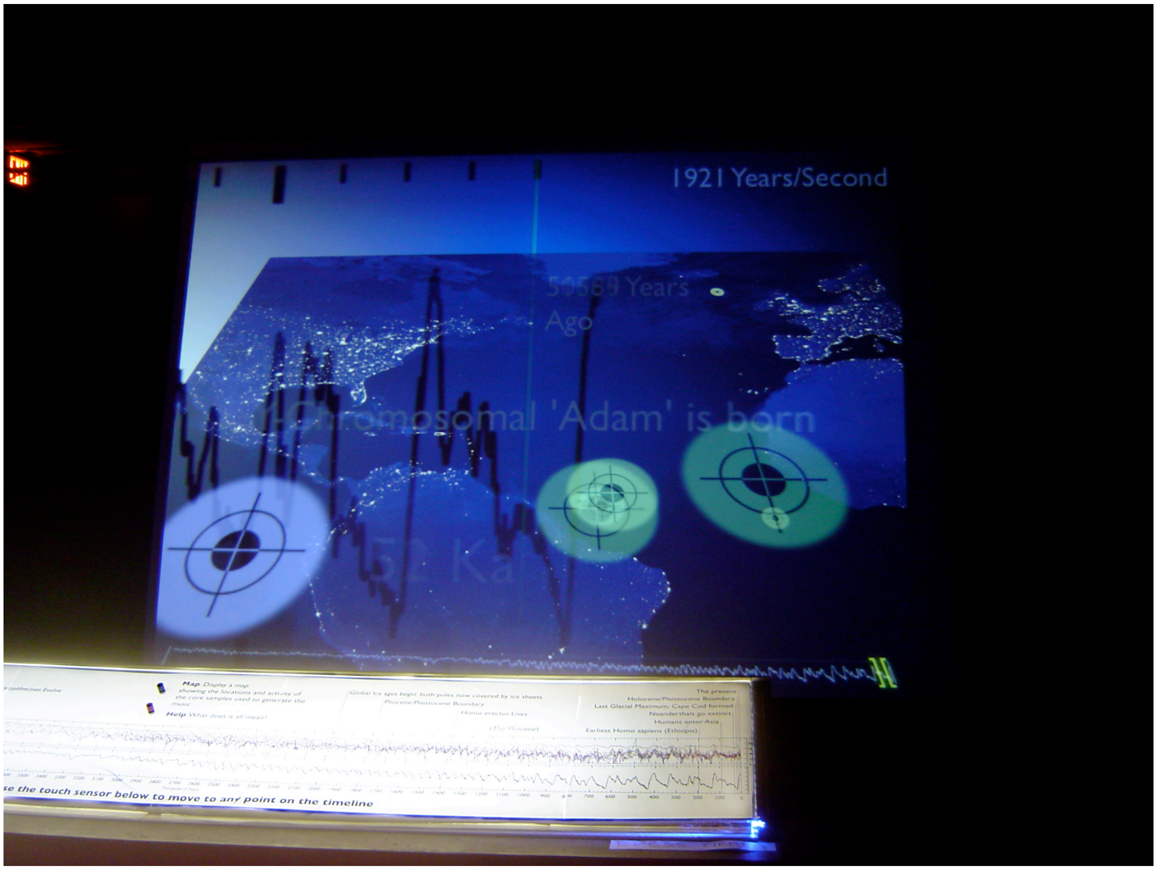


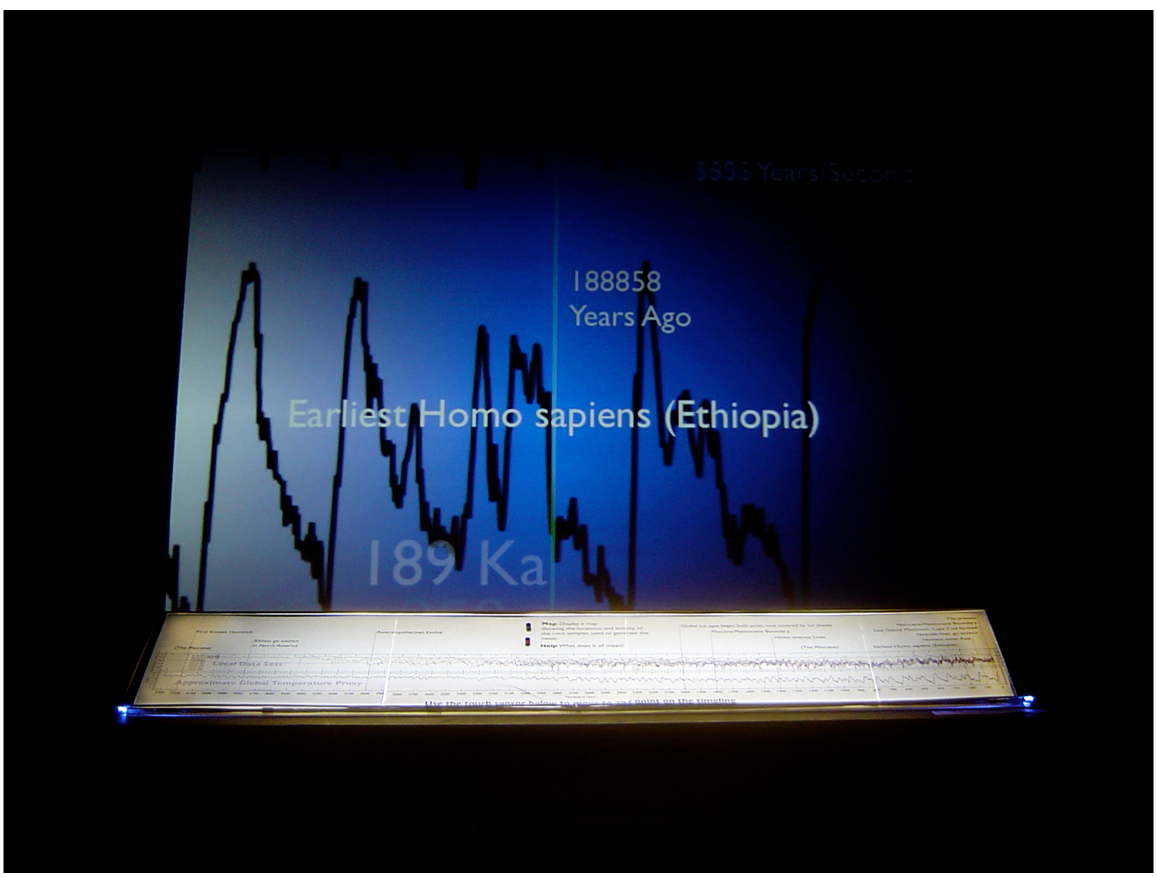
The projection visuals were created in Quartz Composer - a visual OpenGL programming software included free with the Apple Developer Tools. The 'patching' paradigm in this environment is similar to that of Max/MSP.

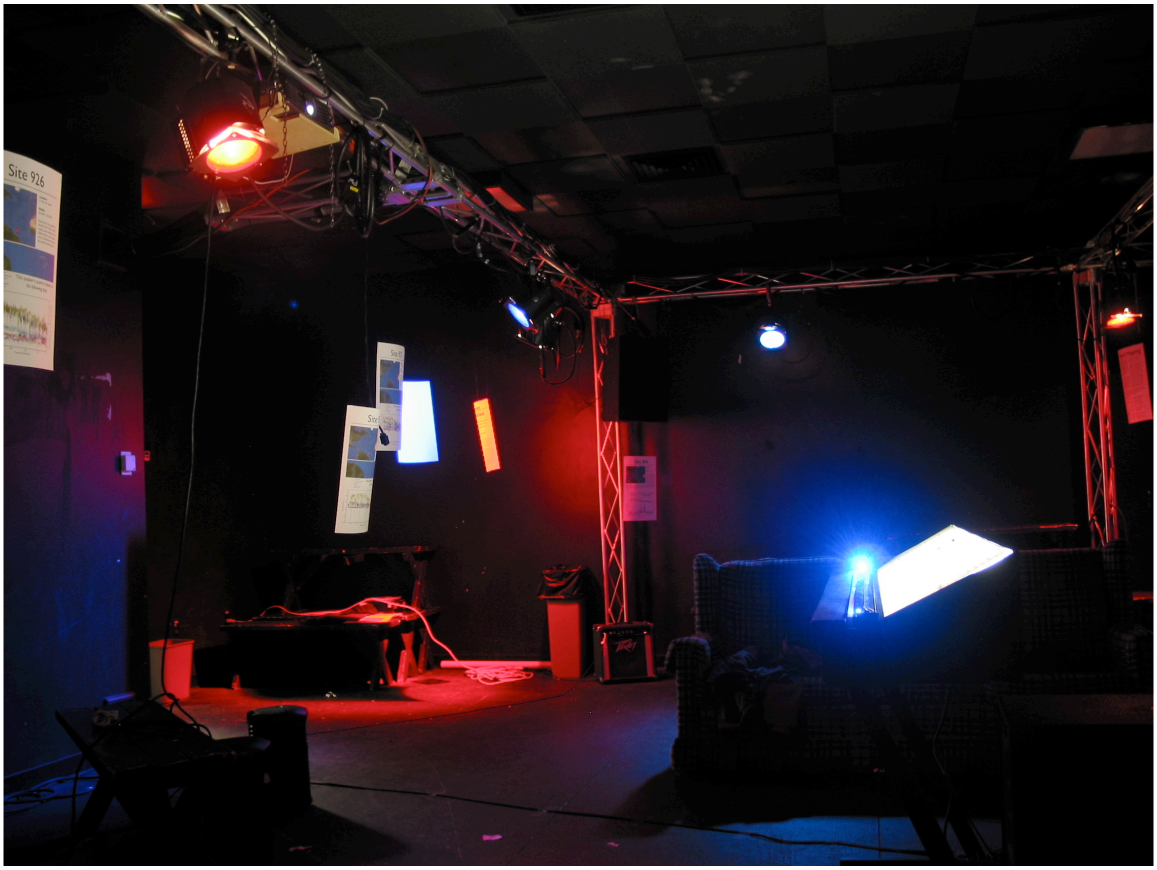
The following screenshot of the software and photo of the timeline interface and projection as realized in the installation, show approximately the same point in time.


Quartz Composer File Edit Editor Viewer Window Help
10:40 PM
GeoSound
Transport
Reset Beginning
Re-Init Tracks
Go To Time (in Ka)
Speed
15.83329 Ka/Second
180.6090 Ka
Master Begin
5320.
Visuals – Viewer
15833 Years/Second
180608
Years Ago
Earliest Homo sapiens (Etheopia)
181 Ka
Frame Rate: 18.14 FPS
Rendering Load: 11%
Visuals – Editor
Patch Library
Clip Library
Root Macro Patch
Bg grad macro
Ya Macro
Ka Macro
p speed
Bonjour Services
Given a Bonjour service type (like "_daap._tcp." for iTunes Music Sharing, "_dpap._tcp." for iPhoto Photo Sharing, or "_presence._tcp." for iChat AV), this patch outputs a structure containing the names of the available services of this type on the local network.
Picture 5
1,280 × 854
Picture 3
1,280 × 854
Autostart_JackOSX_1.2.zip
Picture 4
1,280 × 854
doaçao dum downloa...tear).mp3
01'36
TrashOS 9

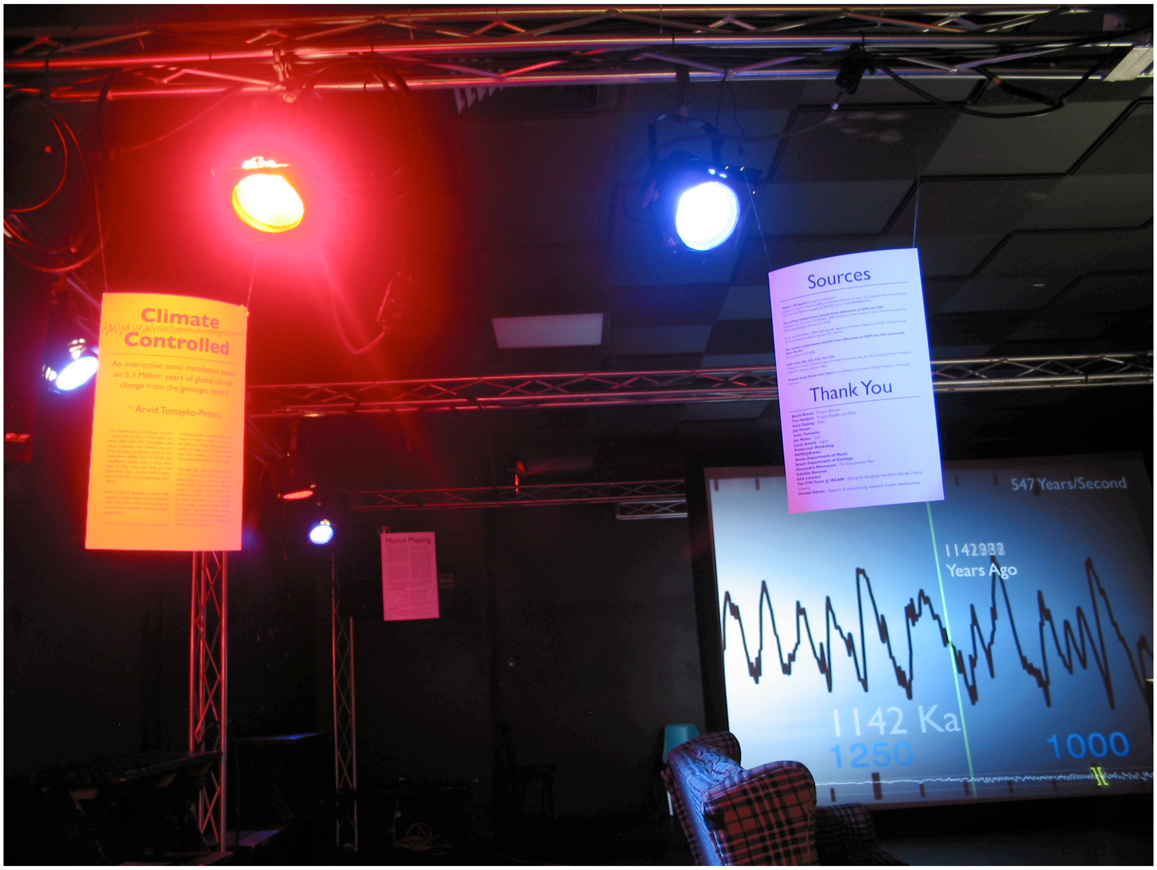

Years/Second
188858
Years Ago
Earliest Homo sapiens (Ethiopia)
189 Ka

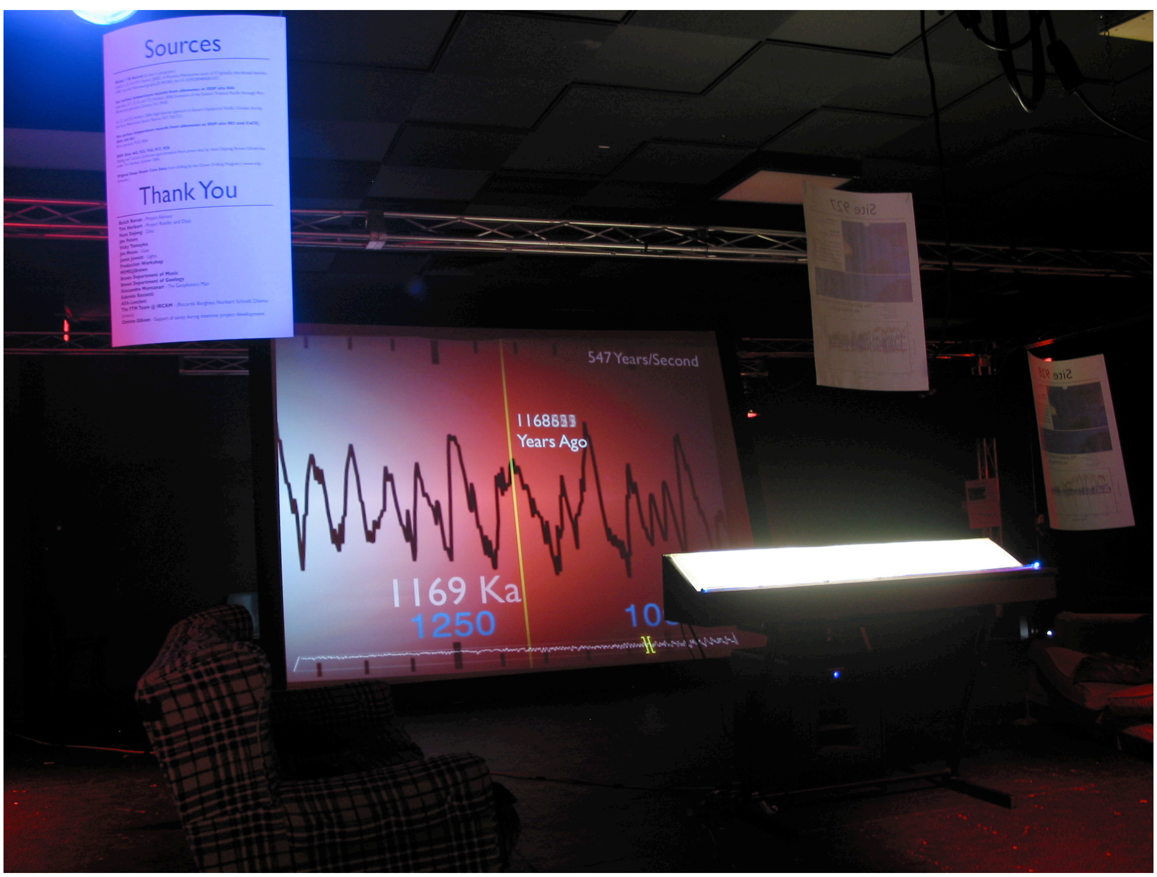

1921 Years/Second
Chromosomal 'Adam' is born
se the touch sensor below to move to any point on the timeline

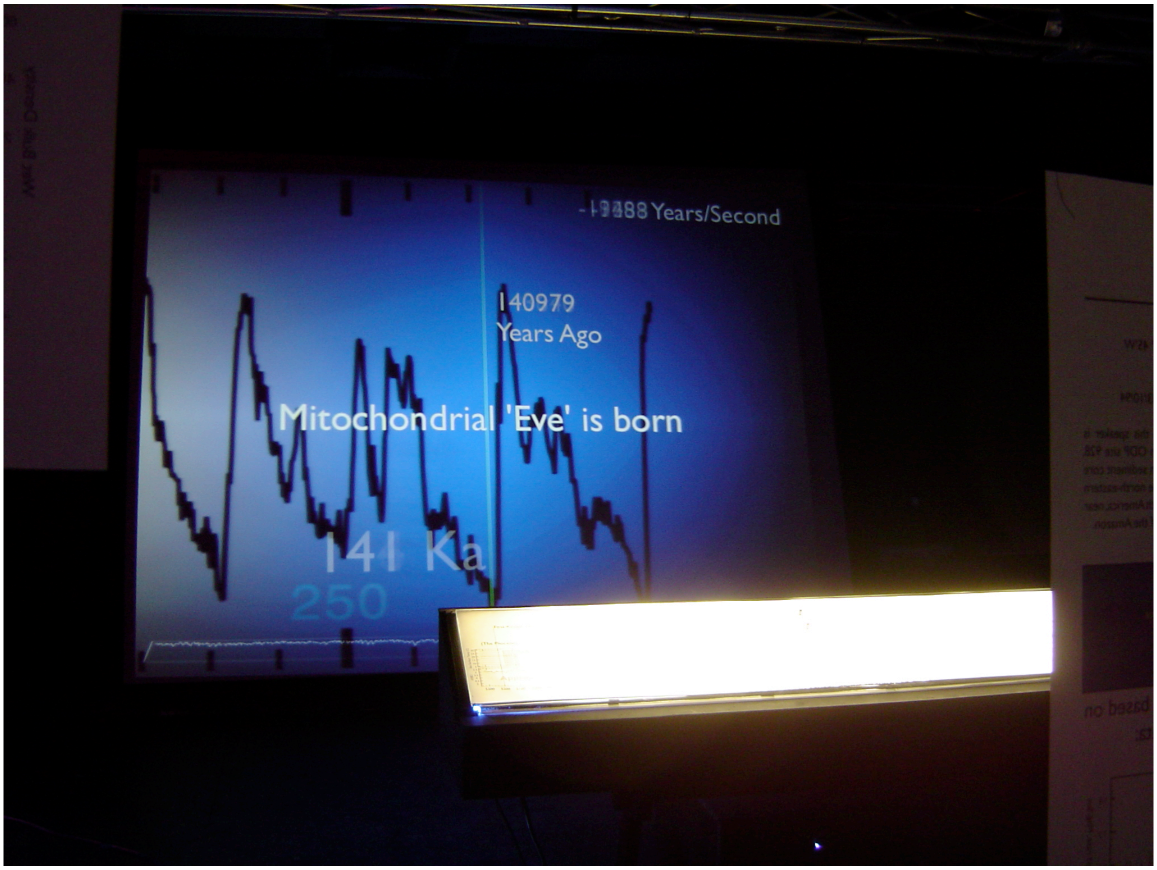

188858
Years Ago
Earliest Homo sapiens (Ethiopia)
189 Ka

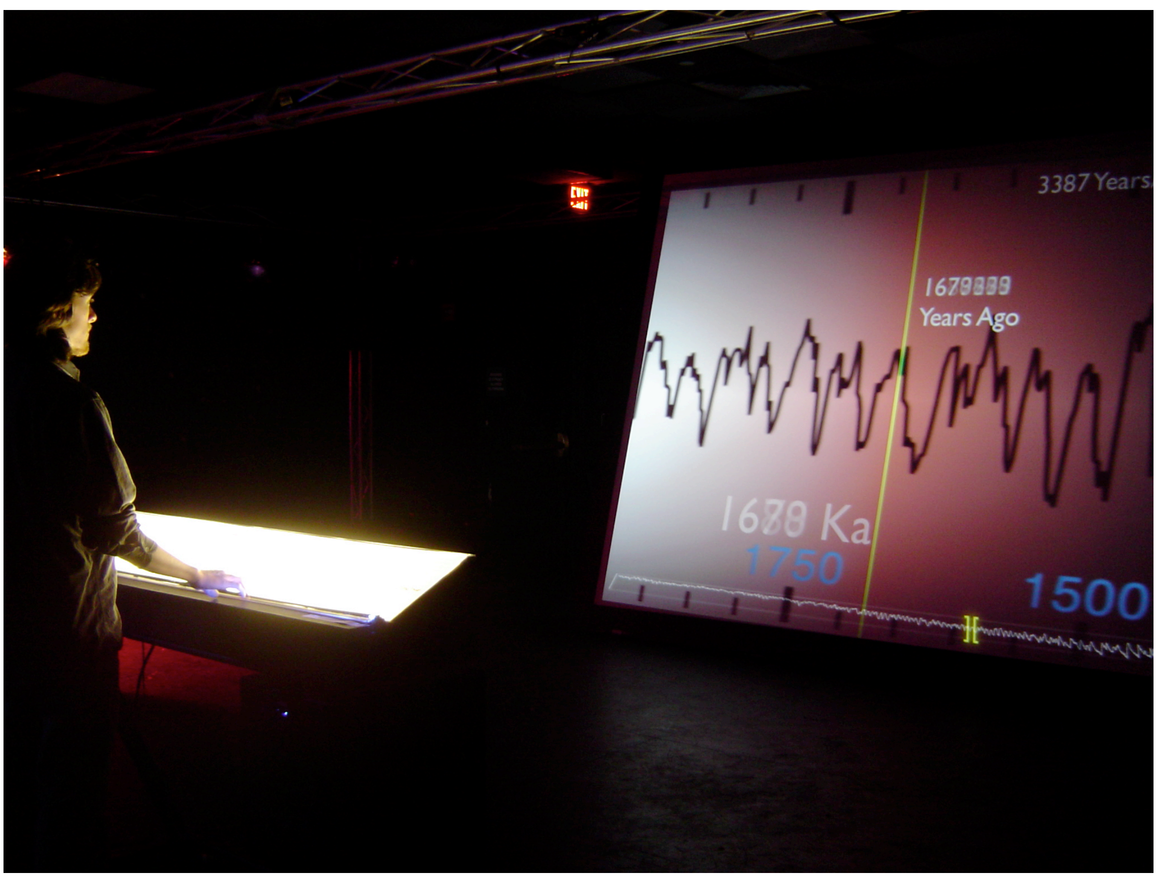

Site 926

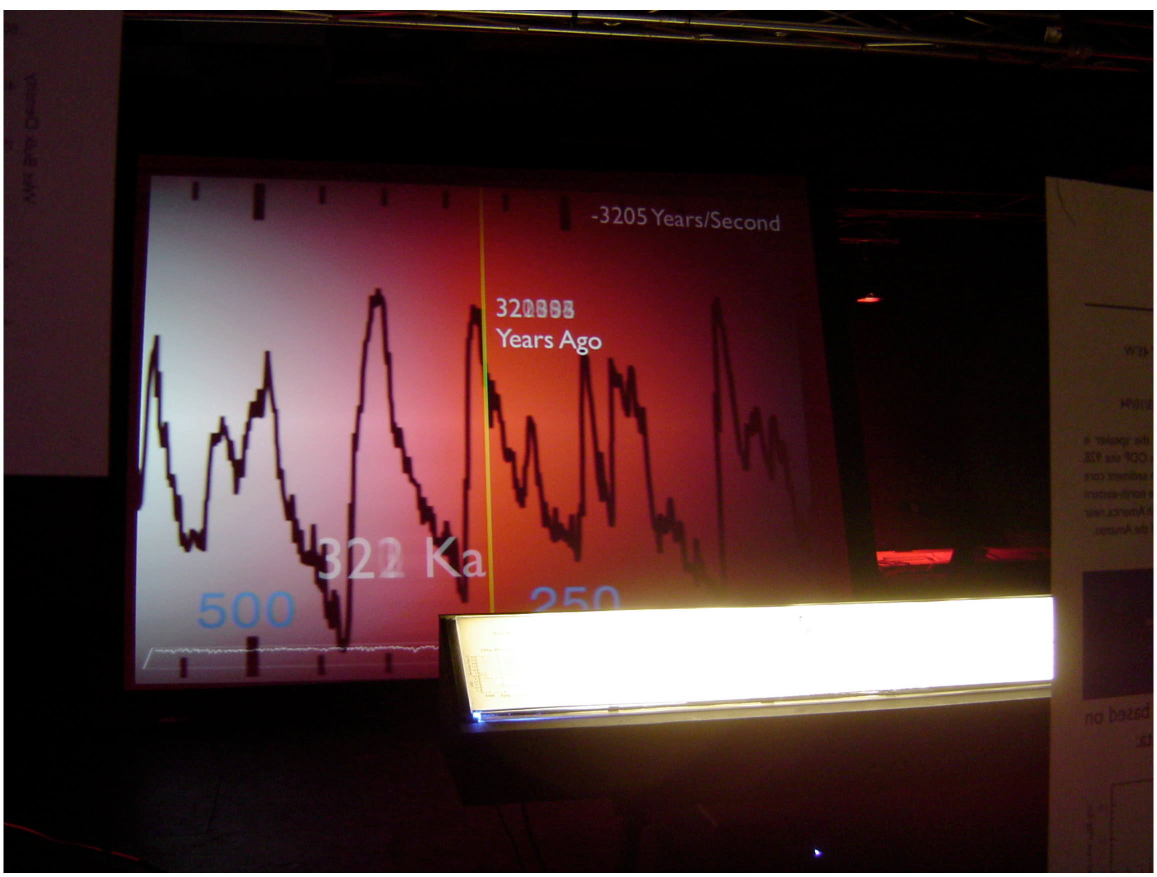

60987 Year
5107350
Years Ago
Hominids


Climate Controlled
An interactive sonic installation based on 5.3 Million years of global climate change from the geologic record
~ Arvid Tomayko-Peters
Sources
Thank You
547 Years/Second
Years Ago
1142 Ka
1250
1000


Sources
Thank You
547 Years/Second
Years Ago
1169 Ka
1250


Years/Second
140979
Years Ago
Mitochondrial 'Eve' is born
141 Ka
250

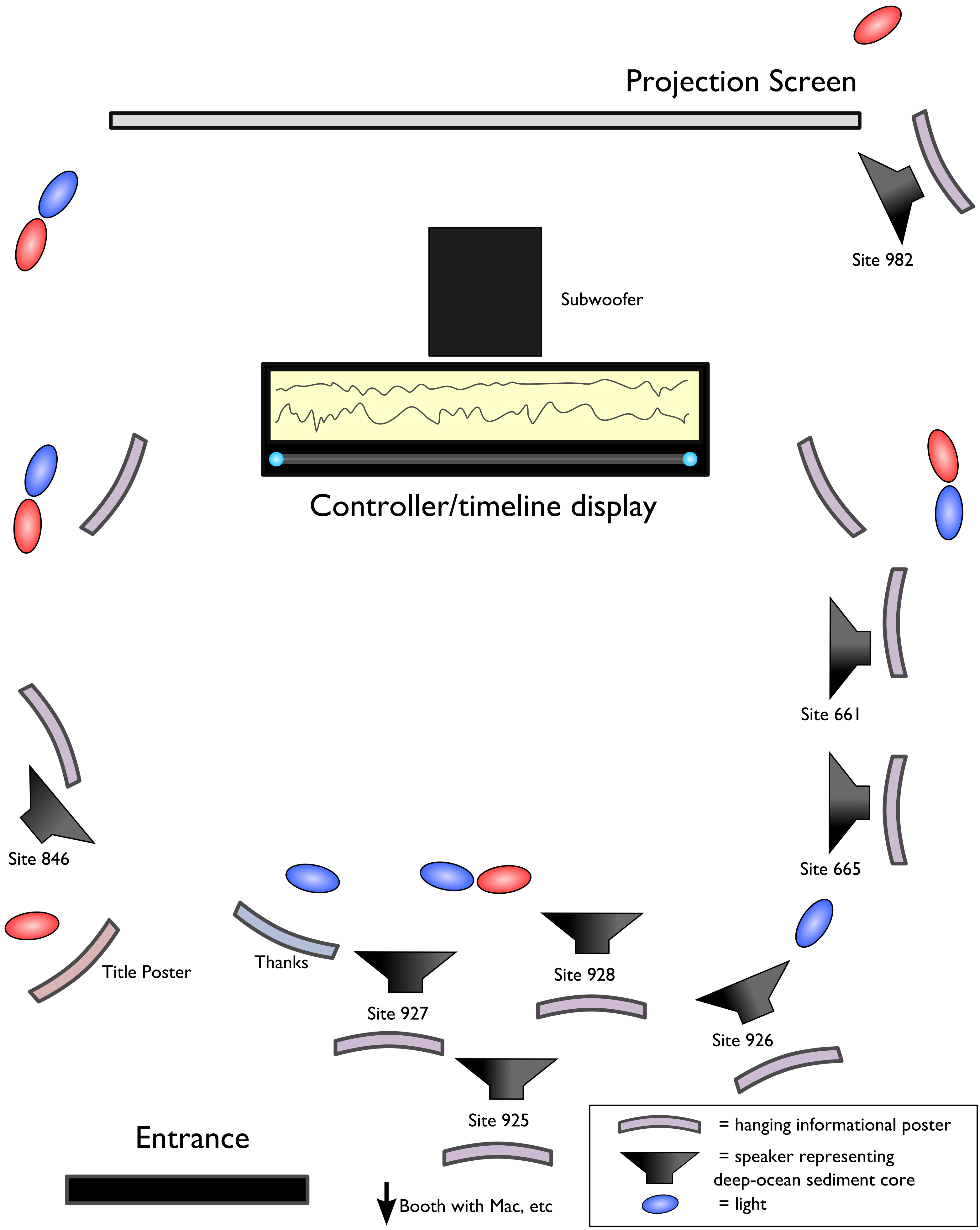

3387 Years
Years Ago
Ka
1750
1500


-3205 Years/Second
Years Ago
500
250

Climate Controlled

Installation Layout

Arvid Tomayko-Peters 2007



Climate Controlled

An interactive sonic installation based on 5.3 Million years of global climate change from the geologic record

by Arvid Tomayko-Peters

This installation is a constant concert - come and sit, stay a while, think, explore (play with the controller) and enjoy. Consider the millions, nay, billions of years of Earth's history that have come before you, of which this installation shows only a very small part. In deep time, our lives are the blink of an eye – and 5.3 million years is not even very long by geologic standards.

Each of the 8 speakers present represents a single deep ocean sediment core, data from which have now become sound. Speakers are placed geographically.

In front of the projection you will find a timeline with a touch sensitive strip. Press it firmly to move to any time, or slide your finger along it slowly to move through time. When you let go, you will continue to travel through time at the last speed of your finger.

You may ask "why Geology and Music?" In geology, if you find yourself measuring vertical distance, you are most likely measuring time. Similarly, music is created from events over time. Since earth processes proceed in many complex cycles and natural feedback loops, patterns should emerge in geophonic music, creating not only an edifying listening experience, but also possibly something that makes sense scientifically.

Sources

Global $\delta^{18}O$ Record (as seen in projection)
Lisiecki, L. E., and M. E. Raymo (2005), A Pliocene-Pleistocene stack of 57 globally distributed benthic d18O records, Paleoceanography,20, PA1003, doi:10.1029/2004PA001071.

Sea surface temperature records from alkenones at ODP site 846
Lawrence, K.T., Z. Liu, and T.D. Herbert, 2006, Evolution of the Eastern Tropical Pacific through Plio-Pleistocene glaciation, Science 312: 79-83.

Liu, Z., and T.D. Herbert, 2004, High latitude signature in Eastern Equatorial Pacific Climate during the Early Pleistocene Epoch, Nature, 427: 720-723.

Sea surface temperature records from alkenones at ODP site 982 and $CaCO_3$ data site 661
Kira Lawrence, Ph.D. 2006

ODP Sites 665, 925, 926, 927, 928
Dating and Calcium Carbonate approximation from proxy data by Hans Dejong, Brown University, under Tim Herbert, Summer 2006.

Original Deep Ocean Core Data from drilling by the Ocean Drilling Program (www-odp.tamu.edu).

Thank You

Butch Rovan - Project Advisor
Tim Herbert - Project Reader and Data
Hans Dejong - Data
Jim Peters
Vicky Tomayko
Jim Moses - Gear
Jamie Jewett - Lights
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Brown Department of Music
Brown Department of Geology
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Gabriele Rossetti
AEA-Loccioni
The FTM Team @ IRCAM - (Riccardo Borghesi, Norbert Schnell, Diemo Schwarz)
Christie Gibson - Support of sanity during intensive project development

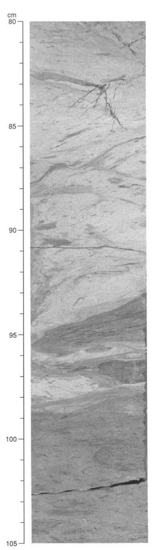
About Cores

The Ocean Drilling Project uses a specially outfitted ship to drill deep ocean sediment cores throughout the world's oceans. These cores are studied by geologists and climate scientists to unravel the history of the Earth's climate.

As is usually the case in geology (though not always) depth corresponds roughly to time: deeper sediment is always assumed to be older. However various factors such as changing sedimentation rates, differing ocean chemistry and sediment compaction from burial make this a very non-linear relationship. Oxygen isotopes read from the cores are usually used to date them by matching them up with a global average, such as the Lisiecki stack seen in the projection. For these cores, most of this work was done by Hans DeJong and Prof. Tim Herbert. Once dates are assigned to depths, data can be fitted to time and analyzed.

An important datum is the amount of $CaCO_3$: it shows a cyclic record of the biological productivity of calcarous organisms and hence the local climate. Measuring $CaCO_3$ in sediment is a time consuming process, so often various proxy data that can be more easily collected are combined and used to estimate $CaCO_3$ content. In many of these cores this is done using a combination of Reflectance (how light or dark a core is), Magnetic Susceptibility (how well it can be magnetized - show show much Iron) and Wet Bulk Density (basically how heavy it is).

To the left you can see some photos of sections of core 925, drilled in the wester equatorial Atlantic. This is used in the piece.



otograph showing folded layers and contorted laminae in a slump rval 154-925A-56R-3, 80–105 cm).

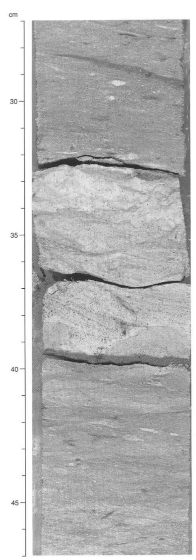


Figure 7. Photograph of a turbidite (interval 154-925A-63R-2, 27–47 cm).

Musical Mapping

Creating sound from data is ostensibly easy. Using a computer, any type of digitized data can, in theory, be converted to any other type. This is the process of 'mapping' - of taking input data and defining how it will control the generation of sound or images. Transmutation, if you will. Computer musicians tend to be interested in synaesthesia - a disorder that results in the mixing of the senses.

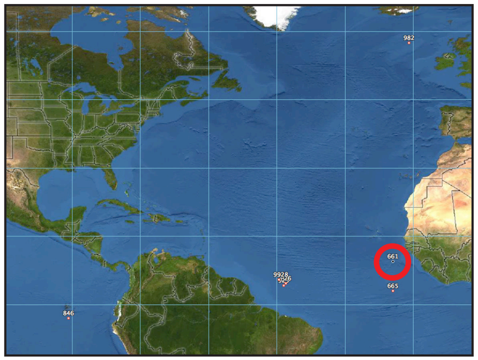
A number of different mappings are used in this project. Some are very direct: for instance converting global d[18]O data (which has, as you can see and hear, a periodic pattern) directly into sound waves by speeding it up billions of times its original speed. Because musical sound is just periodic data. Some mappings are less direct: for instance mapping Magnetic Susceptibility to the center frequency of a filter that is applied to the above mentioned sound waves.

The first step in mapping is to find a meaningful parameter that you want to control with your data. In the case of this project, I built the sound generation engine around the data, so I would try to create a sonic or visual process that could be meaningfully controlled by some type of data I had. The next step is scaling, either linearly or otherwise, of the data to a suitable range, and outputing it at a suitable rate (audio rate (44.1 kHz) or varying data-rates). Sometimes you want to extract logical information from data - are we in a cold period, or not? Or find its rate of change, etc. Finally, there is the continual tweaking to get it to sound right!

Some of the primary mappings used in *Climate Controlled* are as follows:

Global Ice Volume/Global Temperatute (through $\delta^{18}O$)	➝	Color, Ice cracks, base core waveforms
Sites 661, 665, 925-928		
Fraction of $CaCO_3$	➝	Speed (and pitch) of waveforms (more $CaCO_3$ = lower pitch)
Magnetic Susceptibility	➝	Filter 1 Center Frequency
Reflectance	➝	Filter 2 Center Frequency
Wet Bulk Density	➝	Filter Q (more dense = sharper filter)
Sedimentation Rate	➝	Amplitude (High Sed. Rate = Loud)
$CaCO_3$ Accumulation Rate	➝	Amplitude Modulation
Sites 846, 982		
Sea Surface Temperature	➝	Oscillator Pitch (hotter = higher)
Mass Accumulation Rate	➝	Delay Time on Oscillator
Sedimentation Rate	➝	Amplitude (High Sed. Rate = Loud)

Site 661

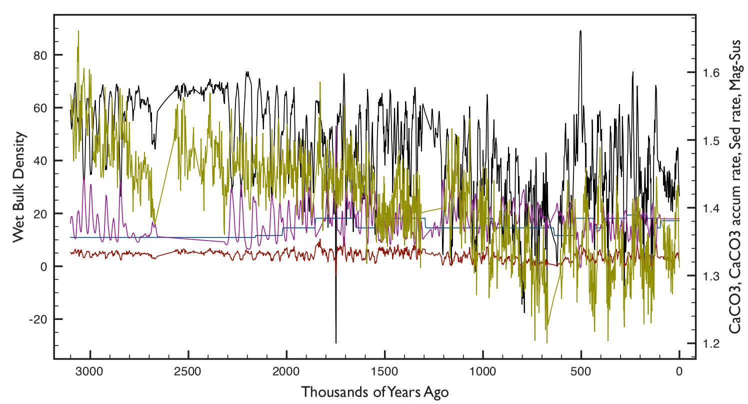


Location:
9° 27'N , 19° 23'W

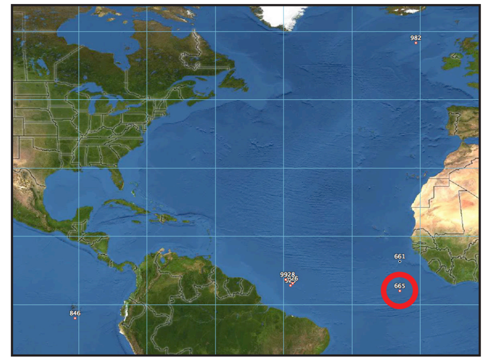
Drilled:
03/17/86 - 03/20/86

Sound from this speaker is derived from ODP site 661, a deep ocean sediment core drilled off the coast of western Africa.

This speaker's sound is based on the following data:



Site 665

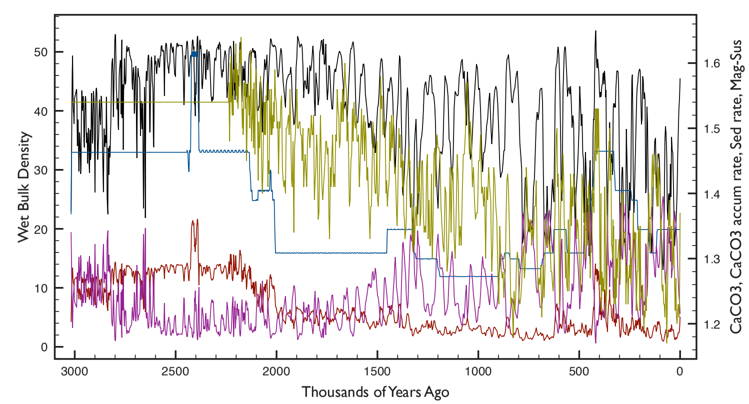


Location:
2° 57'N, 19° 40'W

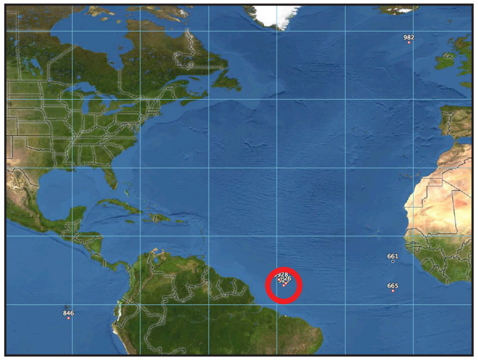
Drilled:
04/03/86 - 04/04/86

Sound from this speaker is derived from ODP site 665, a deep ocean sediment core drilled off the coast of western Africa.

This speaker's sound is based on the following data:



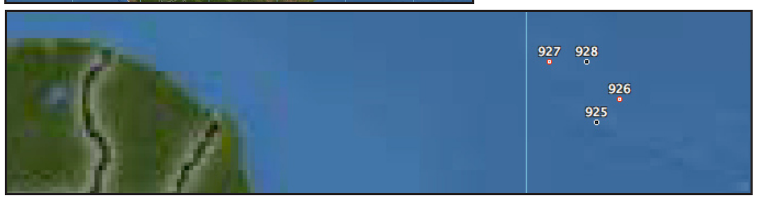
Site 925



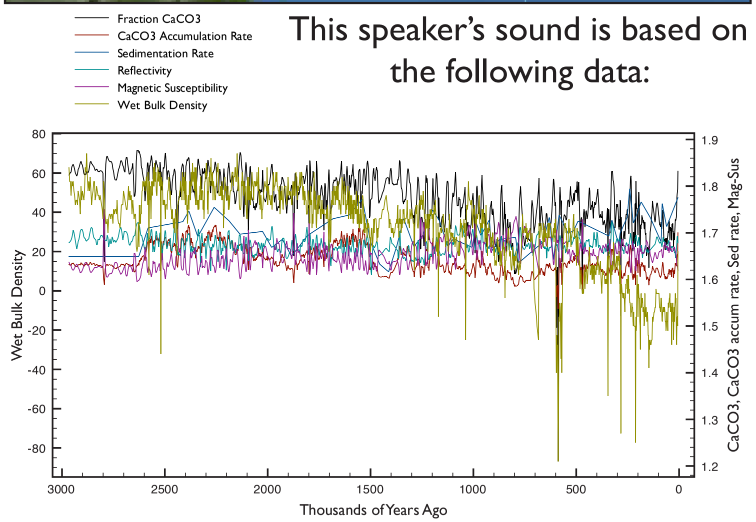
Location:
4° 12'N, 43° 29'W

Drilled:
02/08/94 - 02/19/94

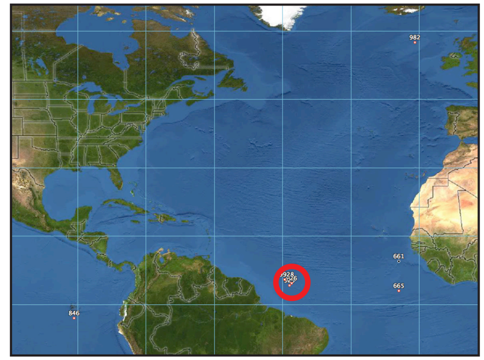
Sound from this speaker is derived from ODP site 925, a deep ocean sediment core drilled off the north-eastern coast of South America, near the mouth of the Amazon.



This speaker's sound is based on the following data:



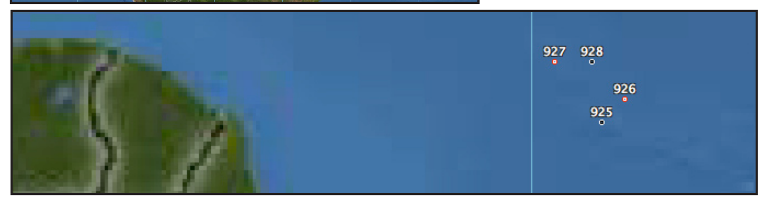
Site 926



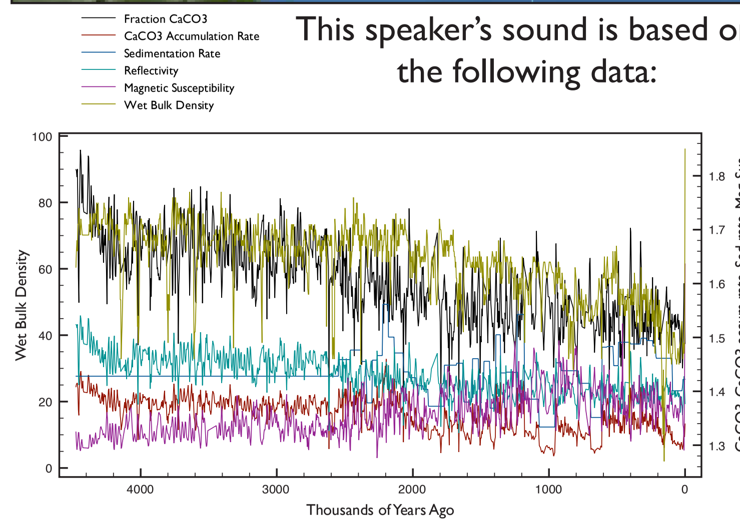
Location:
3° 43'N, 42° 54'W

Drilled:
02/19/94 - 02/27/94

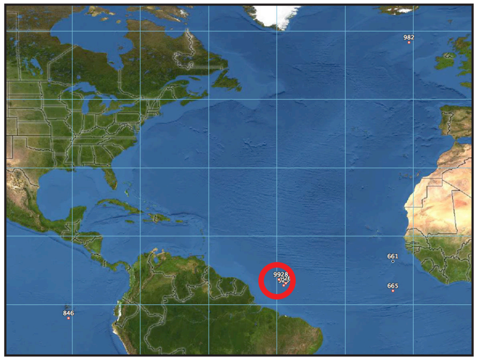
Sound from this speaker is derived from ODP site 926, a deep ocean sediment core drilled off the north-eastern coast of South America, near the mouth of the Amazon.



This speaker's sound is based on the following data:



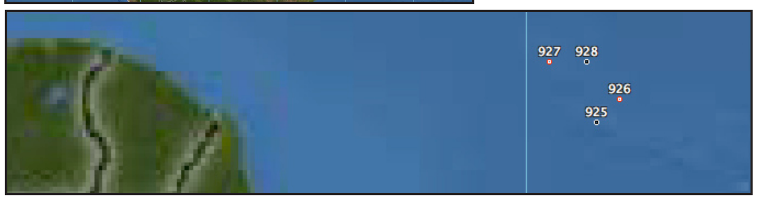
Site 927



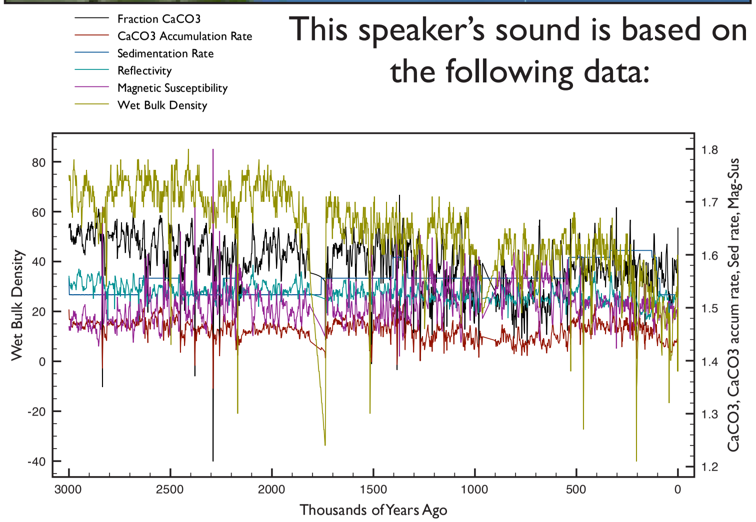
Location:
5° 28'N, 44° 29'W

Drilled:
02/28/94 - 03/04/94

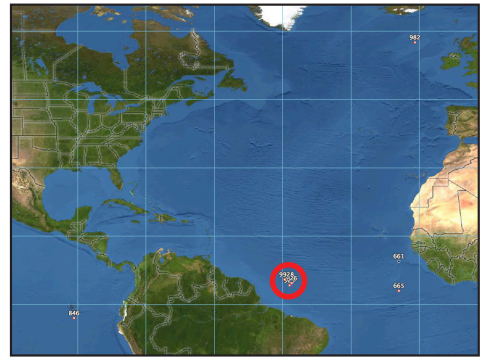
Sound from this speaker is derived from ODP site 927, a deep ocean sediment core drilled off the north-eastern coast of South America, near the mouth of the Amazon.



This speaker's sound is based on the following data:



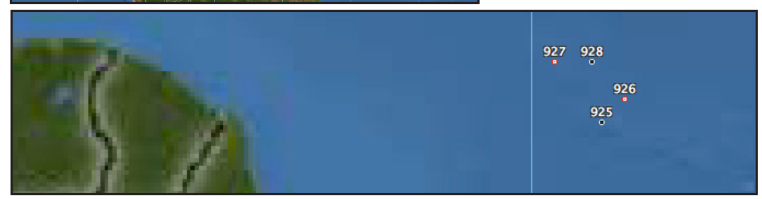
Site 928



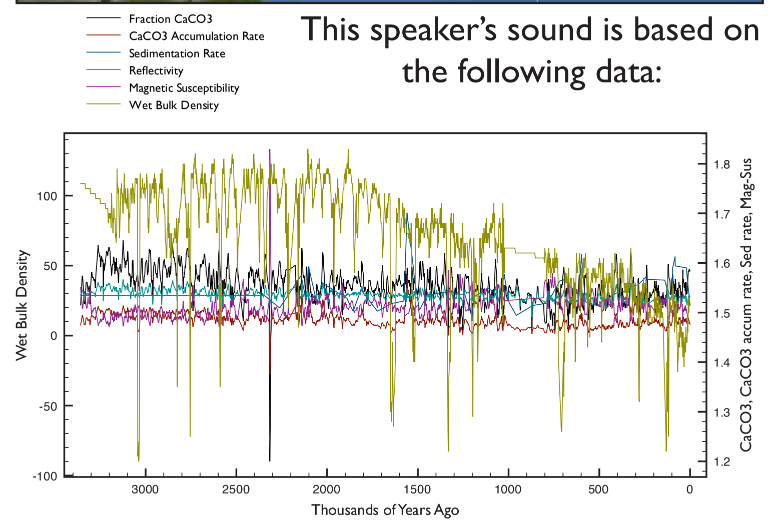
Location:
5° 27'N, 43° 45'W

Drilled:
03/04/94 - 03/10/94

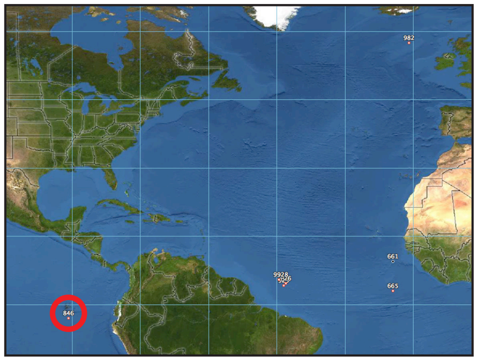
Sound from this speaker is derived from ODP site 928, a deep ocean sediment core drilled off the north-eastern coast of South America, near the mouth of the Amazon.



This speaker's sound is based on the following data:



Site 846

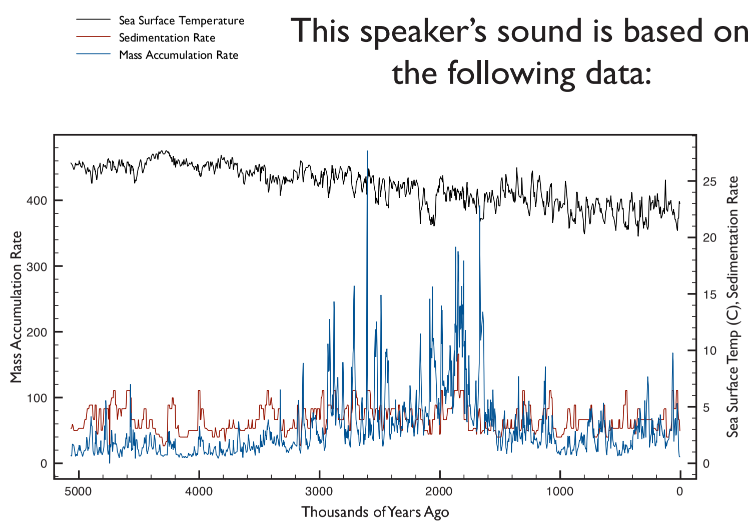


Location:
3° 5'N , 90° 49'W

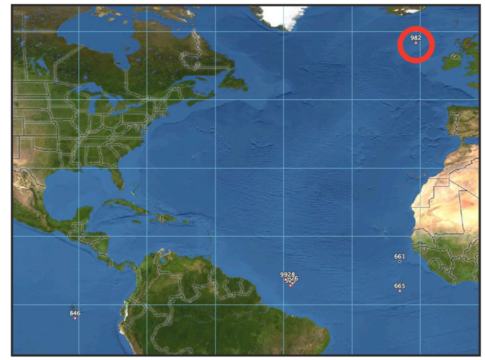
Drilled:
05/21/91 - 05/25/91

Sound from this speaker is derived from ODP site 846, a deep ocean sediment core drilled in the equatorial Pacific. This site was analyzed for alkenones, biogenic chemicals that can be used to accurately reconstruct past sea surface temperatures. These two sea surface temperature (sites 846 and 982) are the longest records, and can be heard by themselves between 5320 and 3000 Ka (thousands of years ago). Special thanks to Prof. Tim Herbert.

This speaker's sound is based on the following data:



Site 982



Location:
57°31.00N, 15°51.99W

Drilled:
07/15/95 - 07/19/95

Sound from this speaker is derived from ODP site 982, a deep ocean sediment core drilled in the northern Atlantic This site was analyzed for alkenones, biogenic chemicals that can be used to accurately reconstruct past sea surface temperatures. These two sea surface temperature (sites 846 and 982) are the longest records, and can be heard by themselves between 5320 and 3000 Ka (thousands of years ago). Special thanks to Kira Lawrence, Ph.D. 2006.

This speaker's sound is based on the following data: