Tree Core and Climatologic Analysis of the CO_2 Event in 1989
Horseshoe Lake, Mammoth Mountain, CA

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Abstract

In 1989, a period of high seismic activity triggered the release of deep magmatic CO_2 into the soil surrounding Horseshoe Lake, resulting in extremely high concentrations of CO_2. Massive tree deaths caused these areas to be known as tree kill areas. Our research attempts to detect CO_2 release from tree growth data. Tree growth rates in the area were determined by measuring tree rings in 84 tree core samples taken from 8 transects near Horseshoe Lake. These growth histories were compared with various weather records in order to account for the influence of temperature and precipitation on tree growth. Weather data collected from various locations in the Bishop-Mammoth area indicate that the local weather trends are relatively insulated from global temperature trends. These factors did not correlate with growth rates sufficiently to account for certain trends in the average tree growth, suggesting that another factor, most likely excess amounts of CO_2, had a major impact on the tree growth. Geochemical data obtained from tree core samples also shows a correlation between Calcium and Iron concentrations and tree growth.

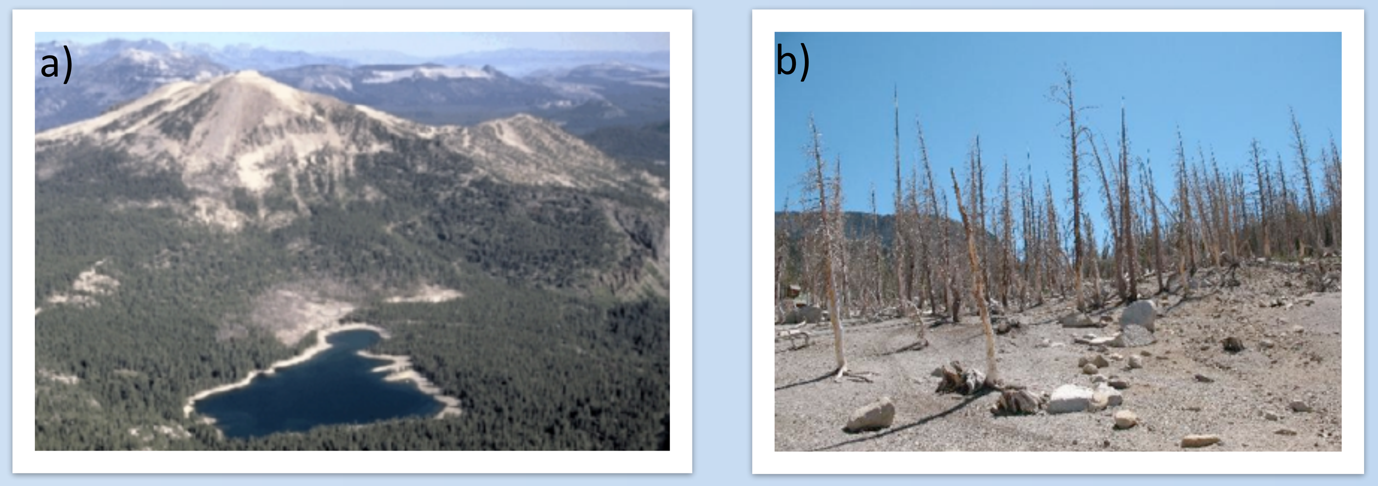

Figure 1: Two pictures of Horseshoe Lake. Picture a) shows an overview of Horseshoe Lake, including the white tree kill areas. Picture b) shows dead trees in tree kill area.

Questions

How does the climatology of Horseshoe Lake compare to that of North America and the World? How does tree ring width vary with temperature and precipitation? Is the big carbon dioxide release of 1989 visible in the tree ring data? Are other carbon dioxide releases visible in the data? Is the carbon dioxide seeping from Mammoth Mountain decreasing or increasing? What elements are correlated with tree ring width?

Hypothesis

We believe that the weather data gathered will exhibit some general trends in terms of temperature with relation to global weather data. Additionally, we hypothesize that the weather data will not correlate significantly with the tree ring widths gathered. Moreover, we believe that the tree ring widths will decline around the year 1989. Currently, we believe that the carbon dioxide seeping from Mammoth Mountain is decreasing. We also think the elemental data for Calcium from the synchrotron will show some sort correlation with the general trends with the ring width.

Methods

Maps

Using ArcGIS and Microsoft Excel, figures were created to show correlations among tree heights and diameters.

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Methods Continued

Ring Width

Tree cores were collected from various areas around Horseshoe Lake. These tree cores were then labeled and sanded in preparation for scanning. The tree ring widths were then calculated. Stacks of average tree ring width were then made for all trees, good trees, summer growth, and winter growth using MATLAB scripts. These stacks were then compared to climate data from several data stations to see if there was any relationship.

Elemental Analysis

Synchrotron data of several tree cores were studied after being normalized for beam jumps. The relative concentrations of these elements were plotted against the tree width plots to see if there was any relationship.

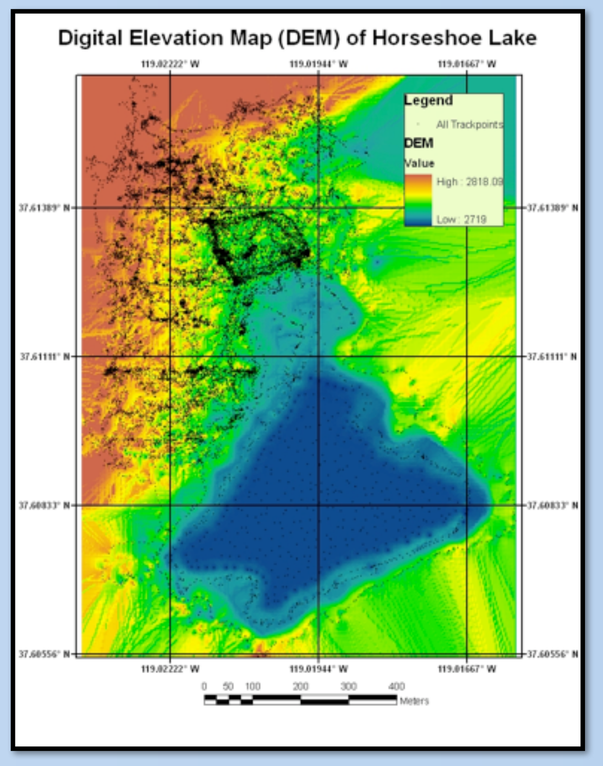

Figure 2: This figure shows the digital elevation map of the Horseshoe Lake area, with the trackpoints that generated this figure shown by tiny black points on the map. The Horseshoe Lake area generally has mountains to the West to the North of the lake.

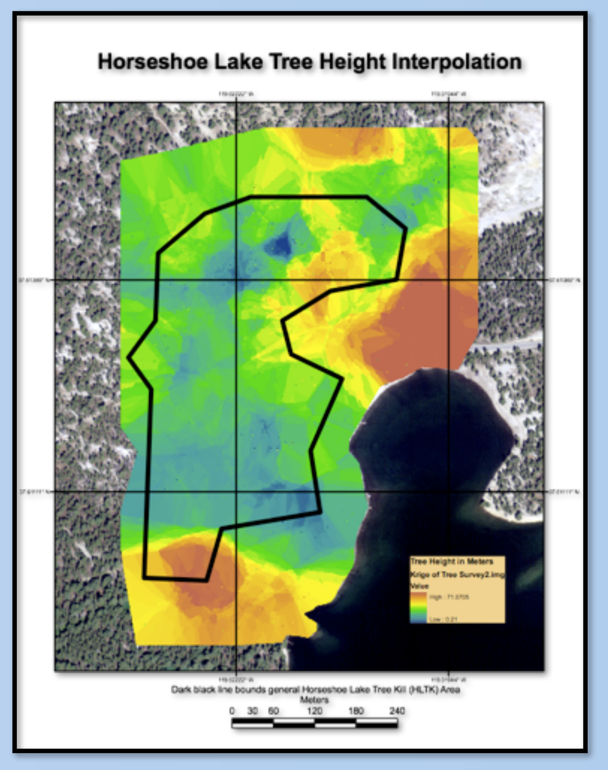

Figure 3: This figure shows the interpolated tree height around Horseshoe Lake from the tree survey. Interestingly, the tree height seems to be much higher in areas outside the general region of the tree kill area. Also, the shorter trees seem isolated to the West-Northwest area of the lake.

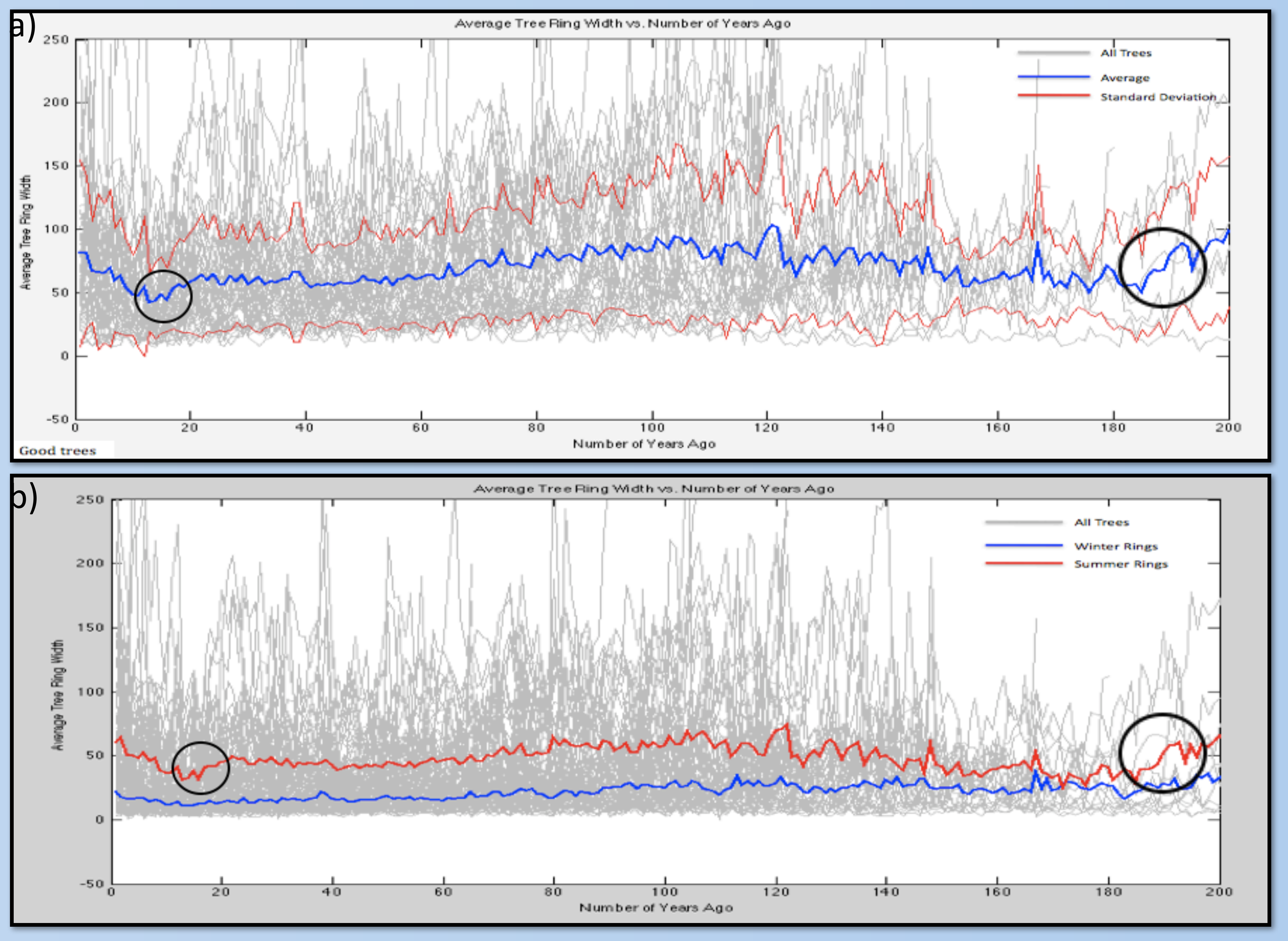

Figure 4: This figure shows plots of average tree ring width versus number of years ago for all trees (a) and seasons (b). Plot a) shows the average tree ring widths for those 60 trees around Horseshoe Lake whose cores we deemed most suitable for stacking versus time. The blue line represents the average widths, while the red lines show one standard deviation above and below this average. The gray lines represent the widths for each tree. Roughly 20 and 190 years ago, the tree ring widths appear to decrease, before a period of recovery in which they gradually increase. Plot b) shows the average summer and winter tree ring growths versus time. The red line shows the thicker average summer widths, while the blue shows the narrower average winter widths. The gray lines represent the widths for each tree. About 20 and 190 years ago, the summer growths decrease noticeably, but the winter growths are not affected as much.

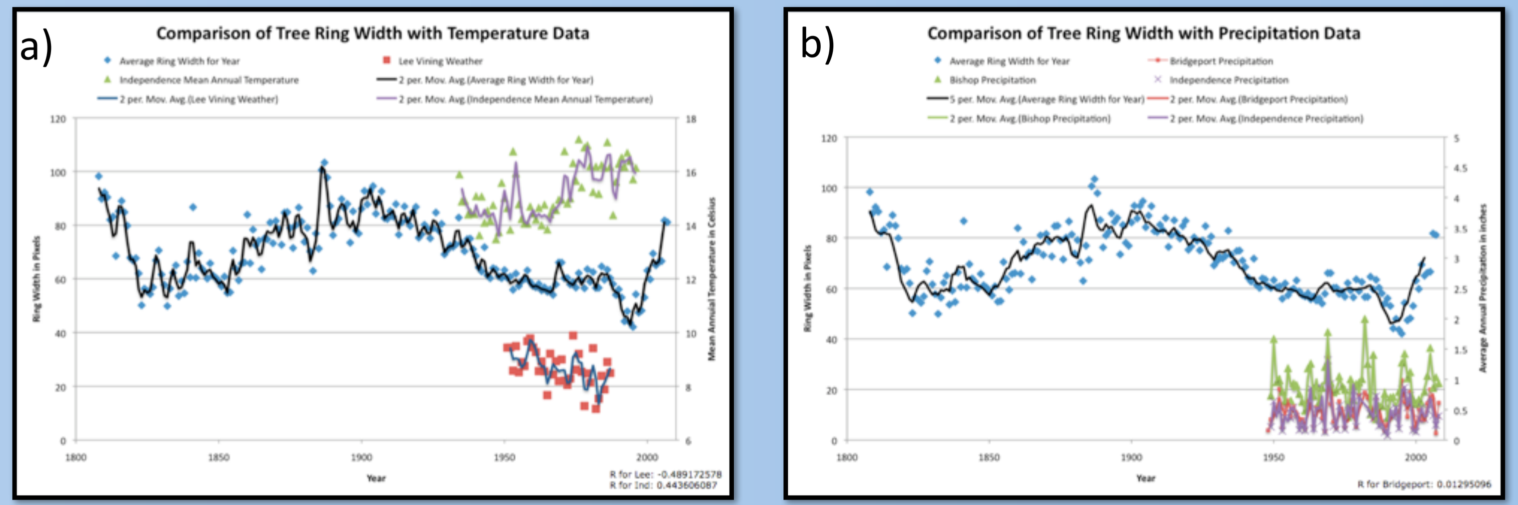

Figure 5: This figure shows the comparison of weather data to tree ring widths. Plot a) compares tree ring width with mean annual temperature from the Independence (purple trendline, about 80 miles south from Mammoth) and Lee Vining (blue trendline, about 25 miles north of Mammoth) weather stations. The general correlation between the temperature data and the tree ring widths is quite high (r values are -0.489 for Lee Vining and 0.444 for Independence). However, the data around 1989 from the Lee Vining station does not show any significant difference from previous years, suggesting precipitation did not cause the drop in tree ring width during 1989. Plot b) compares tree ring width with yearly precipitation from the Bridgeport (red trendline, about 45 miles north of Mammoth), Bishop (green trendline, about 60 miles south of Mammoth), and Independence (purple trendline) weather stations. The general correlation between the precipitation data and the tree ring widths is low (r value for the Bridgeport station is 0.0129). This suggests that changes in precipitation did not cause the dip in ring width around 1989.

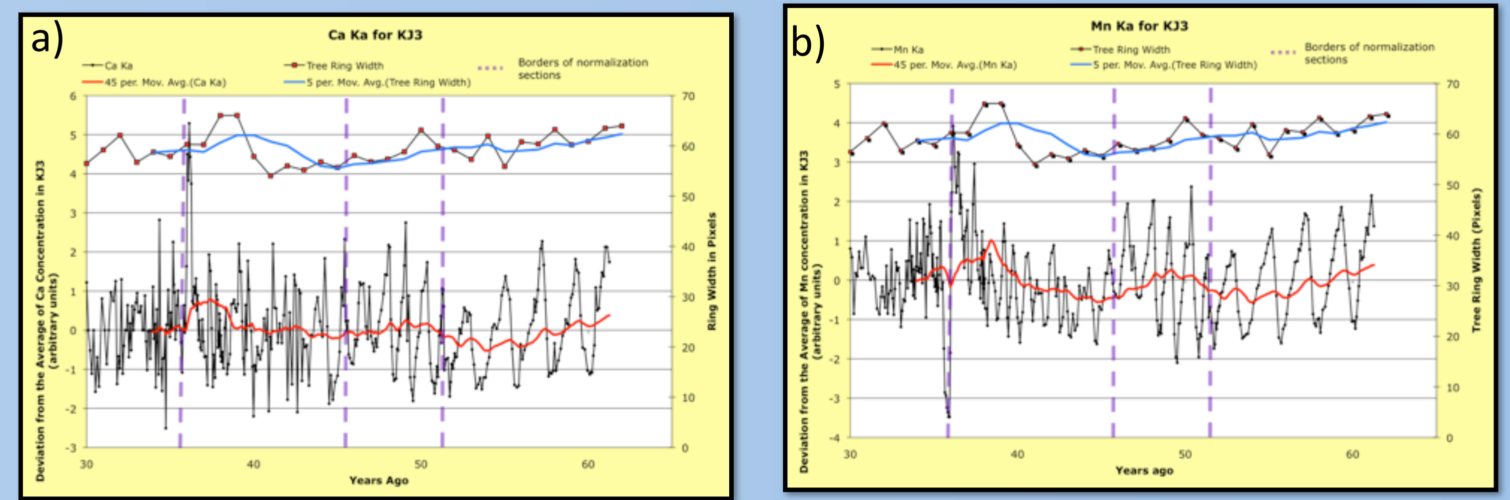

Figure 6: This figure shows two plots of elemental analysis with relation to tree ring widths. Plot a) compares the normalized data for the concentration of calcium present in the tree KJ3 to the average ring widths per year of all the trees cored. The calcium concentration tends to fluctuate in approximately one-year cycles. There is a general correlation between the average ring width per year and the concentration of calcium in the tree. These relationships are particularly marked at the humps in the curves. Plot b) shows the normalized data for the concentration of manganese present in the tree KJ3 plotted with the average ring widths per year of all the trees cored. The Mn concentration fluctuates periodically inroughly one-year cycles as well. There is a better general correlation between the average ring width per year and the concentration of Mn in the tree.

Results and Discussion

Elevation Map and Track Points

The ArcGIS map depicting tree height interpolation in Horseshoe Lake shows that the tallest trees appear outside the tree kill area. It appears that the CO_2 stunted the vertical growth of the trees.

Tree Rings

The average history of tree growth compiled from tree ring data indicates that about twenty years ago there was a rapid decrease in annual tree growth, followed by a gradual recovery period. Seasonally, the decrease is much more apparent in the summer growth rate than the winter growth rate, which is barely affected. The local weather data from this time does not show a significant change in temperature or precipitation that would explain such a decrease in tree growth. Because this sudden decrease correlates with the appearance of excess CO_2 in the soil, it is likely that the presence of CO_2 is responsible for the tree's distress. This would indicate that a high concentration of CO_2 has a significant negative impact on a tree's ability to grow during summer months.

Synchrotron Data

After plotting both the deviation from the average of the elemental concentrations of calcium, manganese, iron, and zinc, and the average tree ring widths against the year, we found a general correlation between the normalized elemental concentration data and the average tree ring width for Ca and Mn. This suggests that certain elements can indicate the relative growth of the tree in a given year. These correlations are most prevalent in the tree core KJ3. In the tree KJ3, Ca and Mn both exhibit approximately one-year concentration cycles. Additionally, these two elements seem to give a good picture as to the relative growth of the tree due to the high correlation.