PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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KECK GEOLOGY CONSORTIUM
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Short Contributions— Paleoclimate Change from Peruvian Lake Deposits Project

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JULIE DANIELS, Northern Illinois University
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HOLOCENE CLIMATE VARIABILITY IN THE PERUVIAN ANDES RECORDED IN PROGLACIAL LAKE SEDIMENTS FROM LAGUNA PEROLCOCHA IN THE QUILCAYHUANCA VALLEY

JULIE DANIELS, Northern Illinois University
Research Advisor: Nathan Stansell

INTRODUCTION

The purpose of this research is to obtain a better record of the climate changes in the Peruvian Andes throughout the Holocene. This is being done through analysis of core sediments from proglacial lakes in conjunction with other proxies for paleoclimate in the area. By comparing the records, a bigger picture can be made for the climate changes that have affected the tropical Andes.

Reconstructing how the climate has changed throughout the Holocene is critical in our ability to predict future environmental changes (Seltzer et al., 2000). Glaciers are sensitive to climate change, so studies of glacier fluctuations can be used as a proxy to determine the timing and pattern of these high-altitude changes. These fluctuations can be linked to ocean-atmospheric dynamics (Vuille et al., 2008). By compiling data on clastic sediment flux to proglacial lakes we can attempt to document the history of glaciation and abrupt climatic oscillations (Rodbell et al., 2008).

STUDY SITE

Laguna Perolcocha (9° 26' 13.776" S, 77° 22' 10.2714 W, 4,720 m a.s.l.; Fig. 1) is in the Quilcayhuanca Valley on the Cordillera Blanca Batholith in Peru. The bedrock there is comprised of Miocene-age granodiorite. Its headwall is at approximately 5,110 m elevation and is currently unglaciated. There is a small, shallow inflow channel on the north end of the lake that flows from an adjacent lake.

Figure 1. View of Perolcocha, facing south. It is located at 4,720 m elevation. On the right is a small inflow channel.

METHODS

Fieldwork

A series of core samples were collected from the depocenter (21.3 m) of Perolcocha. This location was less likely to be affected by mass wasting, wind mixing, and bioturbation. The sediments were collected using a percussion coring system. The top 21.3 cm of sediments were extruded into pre-weighed and numbered Whirl-Pak bags at 1/4 cm increments. The firm lower part of the core was extruded into plastic tubing.

Data Collection

The tubes of sediment cores were brought back to Northern Illinois University where they were further processed. Cores were split vertically into halves and half of each core was designated as an archive while the other half for work. The archive halves of the cores were scanned using a Smartcube® Camera Image Scanner for a high-resolution picture. They were also scanned for magnetic susceptibility (MS) using a Bartington susceptibility meter. The working sides of the cores were sampled over 1 cm intervals for their entire lengths. They were deposited into numbered and pre-weighed bottles. Along with the samples that had been extruded in the field, all the samples were freeze-dried and then weighed again to help determine bulk density.

The geochemistry and sedimentology were determined using a combination of methods. First, all freeze-dried samples were analyzed using an Innov-X Professional® handheld X-Ray Fluorescence instrument (XRF) to determine bulk sediment geochemistry. Once this was done, the samples were analyzed through loss on ignition (LOI). They were heated to 550° for four hours in pre-weighed crucibles. After being removed from the oven they were re-weighed in order to determine the percent organic matter lost. Select portions of the core were also analyzed for biogenic silica ($bSiO_2$) following established protocols (Conley and Schelske, 2001). The percent of clastic sediment was then determined by subtracting the percent organic matter and $bSiO_2$ values from 100% (there was no carbonate present). These values were converted into flux values ($g/cm^2/yr$) by multiplying the clastic component of dry bulk density (g/cm^3) by sedimentation rate (cm/yr) as described by Stansell et al. (2014).

Geochronology

The sediment chronology of Laguna Perolcocha was determined by radiocarbon measurements of aquatic macrofossils taken from eight places throughout the three sediment cores. The samples were wet-sieved with a 250μm screen to isolate the macrofossils, which were picked under a binocular dissecting microscope using tweezers. They were processed in the KCCAMS lab at the University of California Irvine, and the results were calibrated using CALIB 7.1. All of the following dating information is in calibrated years before present.

RESULTS

Geochemistry

The sediment core is characterized by relatively high values of clastic sediment flux between ~ 10 ka and 7.2 ka. Two increases are within this time at ~ 9 ka and ~ 7.6 ka. There are low levels of clastic sediment flux between ~ 7 ka and 6 ka. A noteworthy pulse of clastic sediment flux occurs at ~ 5.3 ka. More recently, between ~ 5 ka and 0.5 ka, the record has been relatively stable with intermediate values.

The percent of titanium (Ti) values in the core are more variable than the clastic sediment flux. There is a period of increased values between ~ 10 ka and 8.9 ka. There is a period of low values before and after this time, with it being low from ~ 8.5 ka through ~ 7 ka. There are two relatively smaller increases, found at ~ 5.2 ka and ~ 3.4 ka. The percent strontium (Sr) values generally covary with Ti. There is an additional period characterized by higher values of Sr found at the beginning of the Little Ice Age (LIA; between ~ 0.5 – 0.2 ka) that is not strongly reflected in the Ti values. The Ti values are still higher at this point than throughout much of the late Holocene.

The percent $bSiO_2$ record for the core has the lowest values in the past few hundred years. The values are at their next lowest at ~ 7.7 ka, where they had dropped from an elevated amount at the beginning of the core (~ 11 ka). After ~ 7.7 ka they begin to trend upwards and hit a high point at ~ 5.5 ka in the middle Holocene. They then decreased on average to a more intermediate level where they remained until the drop in the past few hundred years.

From the beginning of the core at ~ 11 ka until ~ 7.5 ka there is on average less organic matter in the record. There is a decrease where percent organic matter hits its lowest values at ~ 10 ka and ~ 7.2 ka. After that the values trend upwards until it tops out at ~ 6.5 ka. It then drops to lower values at ~ 5.2 ka and again at ~ 3.4 ka with intermediate values between. Sections of the core with high Ti and Sr values have low organic matter content and visa-versa.

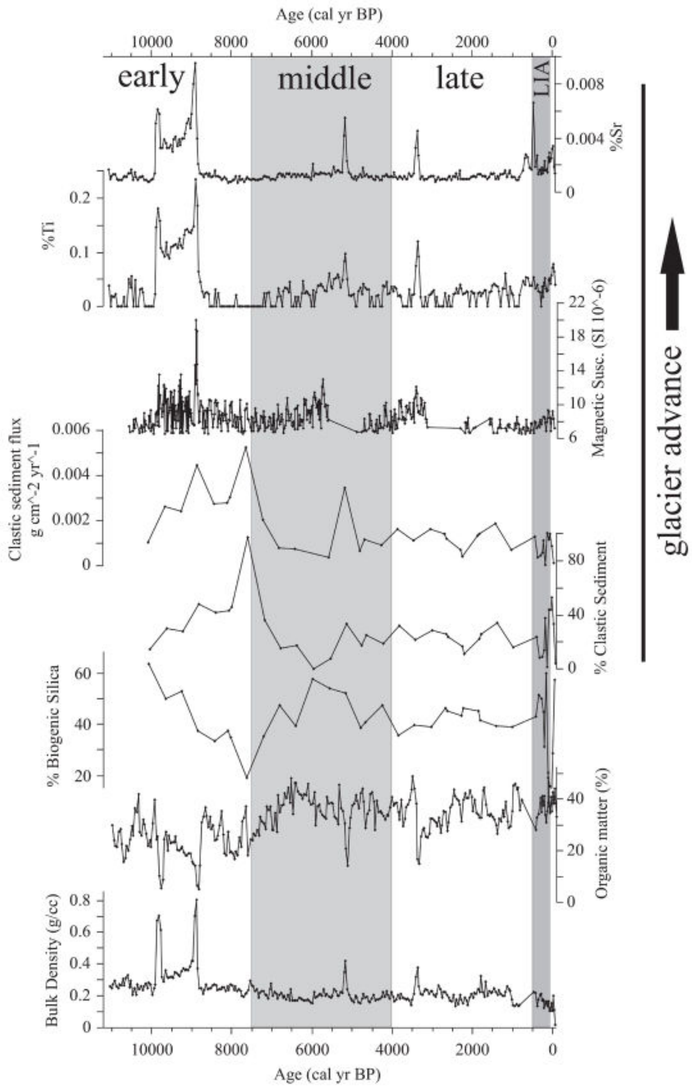

Figure 2. Sediment core data for Perolcocha including clastic sediment flux (g cm-2 yr-1), magnetic susceptibility (SI 10-6), bulk density (g/cc), and percent content for titanium, strontium, biogenic silica, clastic sediment, and organic matter.

DISCUSSION

Currently, the bulk of tropical-latitude glaciers are in the Peruvian Andes. Clastic sediment flux in Andean lakes could be affected by changes in precipitation or glacial processes. If precipitation changes alone were the primary factor controlling clastic sedimentation, then records from both glaciated and non-glaciated valleys would show similar changes in clastic sediment flux. This is not the case, however, as most non-glaciated Andean catchments show little-to-no changes in clastic sediment flux over the last ~ 10 ka. The control on sediment yield in the tropical Andean catchments can therefore be attributed to the extent of glacial ice (Rodbell et al., 2008). Ice advance in the Andes leads to more clastic sedimentation than ice retreat, so when there is increased sedimentation it can be reasoned that there was an increase in glaciation (Leonard et al., 1997). Geochemical measurements can help determine the amount of clastic sediment flux in a catchment. Previous studies have shown that clastic sediment flux is closely associated with other proxies for regional ice cover (Rodbell et al,, 2008).

The Early Holocene (~ 12,000 – 8,000 ka)

Through multiple studies, proxies for climate have lead to the interpretation of the early Holocene as a time of glacial retreat with relatively dry conditions (e.g. Stansell et al., 2013, 2014; Seltzer et al., 2002). In the record for Perolcocha it appears that there was a glacial advance between ~ 10 ka and 8.8 ka. There is evidence of this in both the clastic sediment flux and the geochemical data. It is very prominent in this particular record but has not been found in other lakes within the region. This difference could be due to variations in the local climate or uncertainties in the age model.

The Middle Holocene (~ 8,000 – 4,000 ka)

The proxy records for the middle Holocene are varied. The clastic sediment flux record for Perolcocha around 6 ka has low values that are not seen again until recent, unglaciated times. Combined with low percents of Ti and Sr, this would indicate that the headwall above the lake was ice-free during this time. The clastic sediment flux values are elevated between ~ 5.5 ka and 5 ka. This agrees with the Ti and Sr data, and could be an indicator of a minor advance in glaciation.

The Late Holocene (after ~ 4,000 ka)

The late Holocene appears to be a generally ice-free time for Perolcocha, with notable exceptions. There was possibly a small pulse of glaciation at ~ 3.5 ka based on the Sr, Ti, and organic matter values. Multiple climate proxies for the region agree that this was a time of glacier retreat (Rodbell et al., 2008; Stansell et al., 2013). There is evidence of a LIA advance that can be seen in the upward trend in percents of Ti and Sr, along with a decrease in organic matter. Other proxy records from the region are consistent with this including ice core records, lichenometric studies, and moraine ages (Liu et al., 2005; Licciardi et al., 2009; Solomina et al., 2007; Jomelli et al., 2009).

CONCLUSION

Proxy records of glacial activity in the tropical Andes can be assembled by observing clastic sediment flux in proglacial lakes. In combination with other proxies, they can be used to create a bigger picture of climatic fluctuations and oscillations in South America. The Perolcocha sediment core reflects periods of glacial advances and retreats that are indicative of particular climatic changes. Its sediment record for the early Holocene shows a period of glacial advance with two increases in clastic sediment flux centered on ~ 10 ka and ~ 8.8 ka. Previously published proxies show the early Holocene as being relatively arid and warm conditions (Stansell et al., 2013). More work should be done in this area to determine if there is indeed an early Holocene glacial advance. The middle Holocene was a period of mostly ice-free conditions above Perolcocha. Glaciers retreated through much of the late Holocene including the Medieval Climate Anomaly. There was then a pulse of glaciation that corresponds to the timing of the LIA, where conditions were likely colder and wetter before shifting to what they are today.

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