A 48,000 YEAR RECORD OF CLIMATE CHANGE IN WEST-CENTRAL ARGENTINA FROM STALAGMITES IN CAVERNA DE LAS BRUJAS, MENDOZA PROVINCE

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Past climate changes in the rain shadow region immediately east of the Andes Mountains of west-central Argentina are very poorly known. More detailed climate data are needed to understand what conditions were like when humans first occupied the area and how variations in climate affected these early peoples. We report here on a study of three stalagmites from Caverna de las Brujas (35.80°S, 69.82°W, 1800 m asl), south of Malargüe, in Mendoza Province. Precipitation is approximately 300 mm per year, although interannual variation can be large. Precipitation is somewhat bimodal, with winter precipitation originating from westerlies-driven Pacific moisture spilling over the Andes and summer precipitation largely derived from convective storms fueled by Atlantic and Amazon moisture. Oxygen isotope ratios of precipitation in the region typically range from -1 to -10‰ vs. VSMOW, although extreme low values of -20‰ have been recorded. Monthly $\delta^{18}O$ increases by ~5‰ from a minimum in austral winter to a maximum in austral summer. This increase may be partially explained by the increase in air and cloud temperature during summer months, as well as a change in moisture source during summer to the heavier Atlantic-sourced moisture. No clear correlation with rainfall amount is apparent in modern records. Precipitation $\delta^{18}O$ is likely quite locally variable in this topographically diverse region; however, a lack of long-term precipitation records and coverage limits the current understanding of regional $\delta^{18}O$ controls and variability.

The stalagmites are small, consist of massive calcite, grew relatively slowly, and are light brown in color suggesting humic acids in fluid inclusions. Stalagmite BRU1 is 67 mm high and 7 U-Th ages indicate deposition from ca. 38-15 ka. Stalagmite BRU2 is 153 mm high and 9 U-Th ages show two phases of deposition from ca. 47-39 ka and from 27-17 ka that were separated by a depositional hiatus. The third deposit, BRU-N, is a stalagmite complex 130 mm high, with four distinct growth axes that were each dated and sampled individually. An older core dating to 23-18 ka (2 ages) is overlain by three younger stalagmites each horizontally offset from one another; the oldest dating to 13-7.3 ka (9 ages), the second to 7.3-3.9 ka (7 ages), and the youngest dating from 3.6 ka to recent times (6 ages). Thus, the two simple stalagmites and the complex third stalagmite have provided paleoclimate proxy data for the last ca. 48 ka.

Significantly, deposition of BRU1 and BRU2, and the older section of BRU-N, ceased after ca. 18-15 ka, possibly due to drier conditions in and above the cave. Samples were micro-milled from the three stalagmites for oxygen and carbon stable isotope analysis. Samples from BRU1 (n=70) and BRU2 (n=169) were drilled at a 1.0 mm interval, while samples from the four growth axes in BRU-N (n=349) were drilled at 0.5 mm intervals. Values for $\delta^{18}O$ ranged from -11 to -6.5‰ vs. VPDB, while $\delta^{13}C$ ranged from -7 to +3‰ vs. VPDB. Highest values of both $\delta^{18}O$ and $\delta^{13}C$ are found during the Last Glacial Maximum (LGM). Digital transects of natural light reflectance and ultraviolet-stimulated luminescence along the growth axes of the three stalagmites as well as petrographic analysis of thin sections also provided information on past climate conditions near the cave.

Higher values of $\delta^{18}O$ and $\delta^{13}C$ in the Las Brujas stalagmites are generally interpreted as indicating drier climatic conditions, the first reflecting the kinetic effects of evaporation on soil and cave waters (higher values with increased evaporation) and the second the level of CO_2 in the soil (higher values with decreased CO_2). Other possible controls on stable isotope variability, such as moisture source, ocean isotopic composition, and temperature changes are also being considered. Variations in $\delta^{18}O$ and $\delta^{13}C$ in the Las Brujas stalagmites over the last ca. 48 ka appear to correlate with variations in the $\delta^{18}O$ of ice in the NGRIP core; warmer conditions over the Greenland Ice Sheet broadly match drier conditions at Las Brujas. The high $\delta^{18}O$ and $\delta^{13}C$ values during the LGM suggest very cold, dry, and windy conditions that may explain the existence of extensive contemporary dune fields, such as that north of San Rafael. The time of the Bolling-Allerod (B-A) warm period in the northern hemisphere appears to have been very dry at Las Brujas, coinciding with the Antarctic Cold Reversal (ACR) seen in Antarctic ice cores. Just prior to the onset of the B-A, all three Las Brujas Cave stalagmites stopped growing, and only Stalagmite BRU-N resumed growth afterwards, beginning around 13 ka BP and continuing to the present.

Stalagmite BRU-N has provided the most detailed record of Holocene climate change for any part of Argentina so far. The data show a change to much wetter conditions around 5 ka BP correlating in timing with an increase in Antarctic sea ice and major changes in climate at sites around the world. The BRU-N Holocene isotope record shows that the early and late Holocene were relatively wet in the Mendoza area but that there was a lengthy mid-Holocene dry period that lasted from ca. 8.0-3.7 ka BP with peaks in dryness at 6.5 and 4.5 ka that were separated by a short wet interval at ca. 4.7 ka. This long, dry interval in the stalagmite record correlates with a period of low archaeological visibility in the area that lasted from 6-4 ka; it is likely that people moved out of the area because of the much drier conditions.

The Caverna de las Brujas stalagmite climate records presented here are the first detailed and high-resolution climate records for the last 48 ka for Argentina and as such are extremely important in our understanding of South American and Southern Hemisphere climate changes. Ongoing research on additional speleothems from both Las Brujas and other Argentine sites will continue to advance our knowledge of the region's paleoclimate.