The relationship between use of ice from a lava tube in El Malpais (New Mexico) and drought events in the southwestern USA

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Abstract

The droughts are believed to have influenced settlement and subsistence strategies, agricultural intensification, demographic trends, and migration of the complex Ancestral Puebloans societies that once inhabited the American Southwest. Using precisely radiocarbon dated charcoal from an ice deposit preserved in a lava tube from El Malpais National Monument of New Mexico, we conclude that the population in the region used melted ice for drinking as early as 2000 years ago. The need of constant domestic water supply, especially during major drought events, forced Ancestral Puebloans people to venture into lava tubes and look for ice. Water availability in an already harsh environment may have influenced migrations across the landscape and caused repetitive depopulation-repopulation of some settlement locations.

Résumé

Les relations entre l'exploitation de la glace dans un tube de lave d'El Malpais(Nouveau-Mexique) et les épisodes de sécheresse dans le Sud-ouest des USA. Les sécheresses ont probablement influencé les stratégies de peuplement et de subsistance, l'intensification de l'agriculture, les tendances démographiques et les migrations des sociétés complexes des anciennes populations Pueblos qui occupaient le Sud-ouest américain. En utilisant des charbons de bois provenant d'un dépôt de glace préservé dans un tube de lave du Monument national d'El Malpais au Nouveau-Mexique, et bien datés par la méthode du radiocarbone, nous concluons que la population de la région utilisait depuis 2000 ans la glace fondue comme sources d'approvisionnement en eau. Les besoins constants en eau pour la consommation domestique, surtout pendant les grandes sécheresses, ont obligé les anciennes populations Pueblos à s'aventurer dans les tubes de lave à la recherche de glace. La disponibilité en l'eau dans un environnement déjà rude a pu influencer les migrations à travers le territoire et provoquer un dépeuplement-repeuplement répétitif de certaines régions.

1. Introduction

The Southwest United States has had a history of droughts and climatic hardship long before the occurrence of large scale anthropogenic related climate changes (GRISSINO-MAYER, 1995; CARRILLO *et al*., 2017). Better understanding the climate of the past few thousand years in this region not only sheds light on the struggles faced by the Native Americans and early settlers of the Southwest but may also give us insight into the problems affecting our society in the present and near future. Paleoclimate reconstructions are generated using proxies preserved in biological or inorganic archives that maintain evidence of past climate conditions. New archives are continually sought out by researchers to obtain a more complete picture of our planet's climatic past (LOWE & WALKER, 2015). Ice cores from glaciers and ice sheets have long been a source of paleoclimate data, with oxygen and hydrogen analysis having the potential to reveal temperature records and paleo-moisture sources (GAT, 2010). The isotopic composition of cave ice was first examined by ŞERBAN *et al*. (1967), and later in more detail and using modern calibration techniques by YONGE & MACDONALD (1999), LUETSCHER *et al.* (2005), PERSOIU *et al.* (2017), among others.

El Malpais National Monument (ELMA) is located on the southeast edge of the Colorado Plateau (Fig. 1) and is dominated by basalt flows originating from the Zuni-Bandera volcanic field. The Zuni-Bandera volcanic field has one of the longest spanning volcanic histories in the United States, estimated to range from 700,000 to 3,000 years ago (LAUGHLIN *et al*., 1994).

A lava tube can be described as a type of cave that forms in lava flows where the roof solidifies faster than the middle section, allowing it to empty out and leave a system of tube-shaped cavities (ROGERS & MOSCH, 1997). There are 453 documented lava tubes in ELMA, of which 94 have seasonal and/or perennial ice or have had ice at one time, as indicated by bathtub ring deposits of calcite along the lava tube walls and breakdown piles.

While oxygen isotopes in cave ice in El Malpais have been examined by DICKFOSS (1996), a full paleoclimate record based on isotopic composition of ice has yet to be examined in New Mexico. Here, we contribute to this line of research by documenting five drought events over an 800-year period using well-dated charcoal fragments preserved in an ice core recovered from a lava tube (Cave 29) in the ELMA.

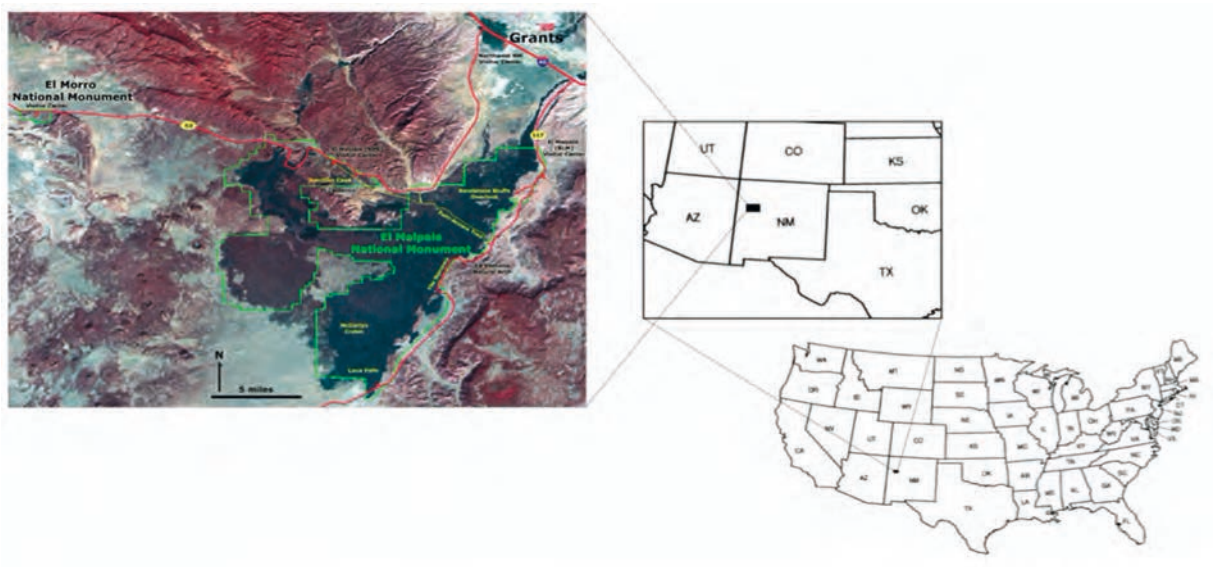

Figure 1: Map of the El Malpais National Monument and its location in the continental USA.

2. Ice and charcoal

Cave 29 opens at an elevation of 2268 m and is a single 171 m long lava tube that splits in two small passages at its very end. The access into the cave is through a large collapse area. The ice block is located in the deeper part of the tube in an alcove and is surrounded by thick (30 to 50 cm) charcoal deposits (ONAC *et al.* 2019). The charred material is only present in the inner part of the tube, beyond a narrow passage that occurs in its middle section. A 59-cm long ice core was recovered from the ice block, photographed, described, and sampled for isotopic analysis (1-cm interval) and radiocarbon dating (whenever charcoal particles existed) were collected while still in the cave.
The ^{14}C ages obtained suggest charcoal was deposited in the ice between AD 167 and 933 (ONAC *et al*., 2019).

Corroborating the presence of charcoal in the ice core with available paleoclimate evidence, it became obvious that Ancestral Puebloans entered deep into the lava tubes during prolonged periods of droughts to harvest ice that they will use for medicinal rituals and also as a source for drinking water.
The *in-situ* discovery of the corrugated Cibola Gray Ware ceramic sherd, its position in relation to the top of the ice deposit, and the presence of charcoal residue coating its interior surface provides insights on the method employed by Ancestral Puebloan people (after ceramic was introduced in the area ~AD 800) to obtain water from the cave ice. Such pots or even sherds could have been used as a platform to support hot coals and/or contain a small fire.

3. Conclusion

Using precisely radiocarbon dated charcoal from a 59-cm long ice core recovered from Cave 29 in ELMA, we unambiguously identified five droughts events between AD 150 and AD 1100. Our findings suggest that the Ancestral Puebloans people ventured into the lava tube and harvest ice. It appears that water availability in an already harsh environment (high elevation lava fields), may have influenced migrations across the landscape and caused repetitive depopulation-repopulation of some settlement locations.

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