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Reconstruction of late Pleistocene climate in the Valsequillo Basin (Central Mexico) through isotopic analysis of terrestrial and freshwater snails

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ABSTRACT

We aim to reconstruct the climatic and environmental conditions in the Valsequillo Basin during the deposition of the Valsequillo gravels between c. 40,000 and 8000 years ago, when large mega-fauna and potentially humans occupied the basin. Fossil freshwater (*Fossaria* sp. and Sphaeriidae (Family)) and terrestrial (*Polygyra couloni*, *Holospira* sp. and Cerionidae (Family)) snail shells from sections within the Barranca Caulapan were collected for oxygen and carbon stable isotope analysis. Oxygen and carbon isotopes in terrestrial and freshwater snail shells relate to local climatic parameters and environmental conditions prevailing during the lifetime of the snail. Whole shell isotope analysis showed that c. 35,000 years ago climate in the Valsequillo Basin was similar to the present day. Between c. 35,000 and 20,000 BP conditions became increasingly dry, after which conditions became wetter again, although this record is truncated. Intra-shell isotopic analyses show that the amount of precipitation varied seasonally during the late Pleistocene. If people did reach this part of the Americas in the late Pleistocene they would have experienced changing long-term and seasonal climatic conditions and would have had to adapt their life strategies accordingly.

1. Introduction

1.1. Background to study

Late Pleistocene deposits are present within the Valsequillo basin, located in the volcanic highlands of central Mexico (N 18° 56, W 98° 07), south of Puebla (Fig. 1A and B). Palaeoclimate records from Mexico for the last glacial period and early Holocene are rather scarce and sometimes contradictory, thus the presence of molluscs within the deposits within the Valsequillo Basin provide an opportunity to obtain much needed additional data. Since the 1960s archaeologists have suggested that archaeological artefacts found in the basin provide evidence for very early human colonization of the Americas. Here we briefly describe the evidence for human occupation in the basin and present new isotope evidence for climatic conditions in the Valsequillo Basin in the Late Pleistocene.

The first geological map of the Valsequillo Basin was produced by H. Malde in 1968. He showed that the underlying bedrock, the Balsas group, is a coarse Cretaceous limestone conglomerate cemented together by a matrix of red mudstone. The Pleistocene Basin deposits were thought to be not more than 70 m thick and to consist of four major units: The Amomoloc lake beds (lower), the Xalnene tuff/ash, the Atoyatenco lake beds (upper), and the Batan Lahar. Malde described the Amomoloc lake beds as rich in limestone, indicative of a closed basin, and the Atoyatenco lake beds as noncalcareous, indicative of external drainage. The intervening Xalnene ash/tuff was thought to represent a very explosive subaqueous basaltic eruption. In the late Pleistocene the Rio Atoyac and its tributaries incised the basin deposits, and this valley system was filled by alluvium known as the Valsequillo gravels, which are presently up to 30 m thick. The lower part of the gravels include many channel deposits of chert and limestone gravels with pebbles up to 0.5 m long interbedded with lenticular finer-grained alluvium and in the upper part fairly regular beds of sand, silt and clay several centimetres thick. Thin layers of volcanic ash, rhyolitic and basaltic, together with pumice lapilli are also present within the gravels sequence (Malde, 1968). From the Valsequillo gravels archaeologists have recovered both humanly modified bone (butchered and engraved) and stone artefacts in association with megafaunal remains (Irwin-Williams, 1962). Since the 1940s a manmade reservoir has filled part of the basin. Meteorological data from Puebla City indicate the present day climate is marked

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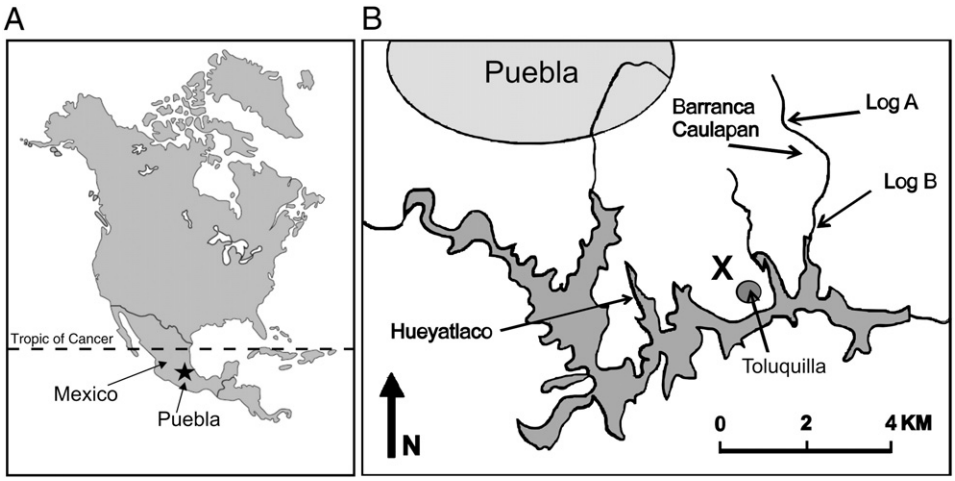

Fig. 1. A. Location of the Valsequillo Basin. B. Location of sections studied in the Valsequillo Basin, Central Mexico.

by highly seasonal precipitation. The region typically receives around 800 mm a year of precipitation which mostly falls between May and October (summer) in response to the northward migration of the ITCZ and the onset of the North American Monsoon. Almost no rain falls between December and February. Annual mean temperatures are around 16 °C, with winter mean temperature around 13 °C and summer mean temperature around 18 °C. In January, the coolest month, temperatures typically range from 8 °C to 17 °C and in April, the warmest month, temperatures typically range from 13 °C to 18 °C. In winter months there can be occasional ground frost (http://www.weatherbase.com).

Fieldwork undertaken within the basin through the 1960s and in 1978, mostly focused on the archaeological site at Hueyatlaco (Fig. 1B), which Irwin-Williams interpreted as being a 'kill site' (Irwin-Williams, 1978). Dating of the Valsequillo gravels at Hueyatlaco and the artefacts within was problematic (see Szabo et al., 1969; VanLandingham, 2004, and González et al., 2006a,b). Subsequent work at Hueyatlaco suggests that the sediments are unlikely to be in situ and that the early uranium series and fission track dates are erroneous (González et al., 2006a,b).

González et al. (2006a) confirmed Szabo et al.'s (1969) results that the Valsequillo gravels in the Barranca Caulapan, a small river gully found on the northeast side of the Valsequillo basin (Fig. 1B) are in situ and date from 38,900 to 9150 ^{14}C BP (uncalibrated). One shell radiocarbon dated to c. 20,000^{14}C BP and was found in close proximity to a lithic scraper, suggesting that humans may have been present in the Valsequillo Basin at this time (Szabo et al., 1969). The partial adult human skeleton found in Texcal Cave in the Valsequillo basin provides incontrovertible evidence for the presence of humans by the early Holocene with a radiocarbon date of 7480 ± 55 ^{14}C BP for the skeletal remains (González et al., 2003).

Markings within the Xalnene ash from Cerro Toluquilla (Fig. 1B), initially interpreted as human footprints relating to a pre-40,000 BP human migration phase, have been re-interpreted as quarry marks (Renne et al., 2005; González et al., 2006a; Feinberg et al., 2009; Mark et al., 2010; Morse et al., 2010).

Although uncertainties remain concerning when humans were first present in the Valsequillo basin and the overall chronology of the basin, the age of the Valsequillo gravels themselves is well constrained (as described above). For this reason, along with the extensive presence of megafaunal remains within this stratigraphic unit and the possible presence of humans within the basin at the time this unit was deposited, we focus our palaeoenvironmental investigations on these gravels. This paper aims to reconstruct the climatic and environmental conditions in the Valsequillo Basin during the deposition of the Valsequillo gravels, when large mega-fauna and potentially humans occupied the basin.

Within the basin we have studied two sections through the Valsequillo gravels that are visible in exposed sections within the Barranca Caulapan (Fig. 1B). Today the Barranca contains an ephemeral stream, fed by a small number of springs, which cuts through the Valsequillo gravels. The Quaternary gravels are observed to overlie the Tertiary Balsas conglomerate, with an unconformity between the two. Samples were collected from two exposed sections one located upstream (Upper Barranca Caulapan, Log A, Figs. 1B and 2) (N 18° 56′ 53.8, W 98° 07′ 48.7, elevation 2091 m), and one downstream (Lower Barranca Caulapan, Log B, Figs. 1B and 3) (N 18° 56′ 36.1, W 98° 07′ 32.2, elevation 2064 m at base of sequence) of the road which intersects the Barranca. The sedimentology and stratigraphy for these two sections are shown in Figs. 2 and 3. Fossil shells of both freshwater and terrestrial molluscs were collected directly from the exposed section face for radiocarbon dating and stable isotope analysis. Modern shells of terrestrial and freshwater molluscs were also collected from leaf litter and rock pools to compare directly with the isotopic composition of the fossil shells and aid with the environmental reconstruction.

1.2. Ecology of the molluscs

1.2.1. Terrestrial snails

Modern and fossil land snail shells collected from the Barranca Caulapan include a Cerionidae, *Holospira* sp., *Polygyra couloni* (Shuttleworth, 1852), *Hawaiia minuscula* (Binney, 1840) and *Rotadiscus hermanni hermanni* (Pfeiffer, 1866). Of these, an unknown genus of the family Cerionidae and a *Holospira* sp. were first found in the Barranca Caulapan as fossil specimens during this research. They will be described and named by Naranjo elsewhere. The three terrestrial mollusc types which were analysed for carbon and oxygen isotopic composition were modern and fossil Cerionidae and *Holospira* sp. and fossil *P. couloni*. Not all specimens of the Cerionidae and the *Holospira* were identified to species level, therefore isotopic data for the Cerionidae and *Holospira* sp. are considered collectively and hereafter are referred to as Cerionidae/*Holospira* sp.

Most of the known species of the family Cerionidae live on exposed shores in the Florida Keys, the Bahamas, the Greater Antilles (except Jamaica) to the Cayman Islands and Curaçao (Pilsbry, 1946). The American mainland distribution of the family in the past was possibly very extensive, since fossil material from the Uppermost Cretaceous Hell Creek Formation, Montana and early Miocene Tampa Limestone of Florida (Roth and Hartman, 1998) had been assigned to Cerionidae. The presence of this cerionid in central Mexico extends its distribution south, along with new species of extant cerionids from Queretaro state, recently described by Fred G. Thompson (manuscript in revision). Living cerionids can be found in isolated patches of pine