



## The Late Pleistocene and Holocene palaeoenvironmental context of Wonderwerk Cave in the southern Kalahari, South Africa

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Wonderwerk Cave, located in the arid southern Kalahari in South Africa, is an exceptional site, since it preserves a two million year long record of human occupation. While research on older levels in various excavation sections of the cave deposits is ongoing, we focus here on the younger levels that span the last 35,000 years. We present the results of past and recent work on zooarchaeology, macrobotany, palynology, phytoliths, stable isotopes, micromorphology and speleothem growth, which track marked diachronic environmental fluctuations.

Except for a hiatus of ~33–23 ka, growth and isotope data for a speleothem near the cave entrance suggests moist conditions from ~35–33, and ~22–14 ka with brief, dry episodes at ~34, ~22 and ~15 ka. Temperatures were cool except for an increase ~16–14 ka after which cold conditions equivalent to the Younger Dryas event occurred. In Stratum 5 (>12.5 ka in Excavation 1), relatively low carbon isotope ( $\delta^{13}\text{C}$ ) values, pollen in the speleothem, and pollen in dung deposits indicate that the vegetation included a large  $\text{C}_3$  component during this phase. While the climate experienced sharp fluctuations in moisture when stalagmite growth was interrupted, more severe drying occurred by ~12 ka as indicated by dung pollen. Pollen in Stratum 4d (undifferentiated by stratum sub-phases) suggest that warmer grassy conditions developed before 11 ka, which is supported by  $\delta^{13}\text{C}$  values in OES that suggest a greater  $\text{C}_4$  plant component in Stratum 4dII associated with the Oakhurst-like archaeological industry. Undifferentiated Stratum 4d indicates moderate moisture availability (pollen) but sub-phase 4dII suggest drying (OES  $\delta^{18}\text{O}$ ).

$\text{C}_3$ -presence (OES  $\delta^{13}\text{C}$ ) in the vegetation became stronger again in Stratum 4dI (Oakhurst) and Stratum 4cII (Wilton). This is supported by Asteraceae pollen especially ~8.5 ka. Except for a fluctuation in OES  $\delta^{18}\text{O}$  values in Stratum 4cII,  $\delta^{18}\text{O}$  and pollen and micromammal composition suggest progressive aridity until ~6 ka (Stratum 4bII).  $\delta^{18}\text{O}$  values on OES indicate a marked shift to a moister episode in the mid-Holocene between 5.9 and 4.9 ka while pollen, phytoliths and microfauna indicate that more grassy vegetation with woodland developed ~5.5–4.4 ka (Strata 4bI–4aLH, Wilton).

A trend towards more arid conditions culminated ~2.8–1.2 ka (Strata 3a–2b, the Ceramic Later Stone Age) as suggested by oxygen and carbon isotopes in OES, and is consistent with pollen and phytolith data indicating vegetation with  $\text{C}_4$  grasses. The macrofaunal data corroborate this picture, with grassland environments increasing through the Holocene as reflected in an increase in grazers; frequencies of springbok (*Antidorcas marsupialis*), a species that suggests aridity, rises from 0% in the early Holocene, to 10% in the mid-Holocene, and further to 16% in the Late Holocene. The general arid trend has continued until a slight increase in moisture availability ~0.8 ka leading up to modern semi-arid conditions in the uppermost disturbed strata.