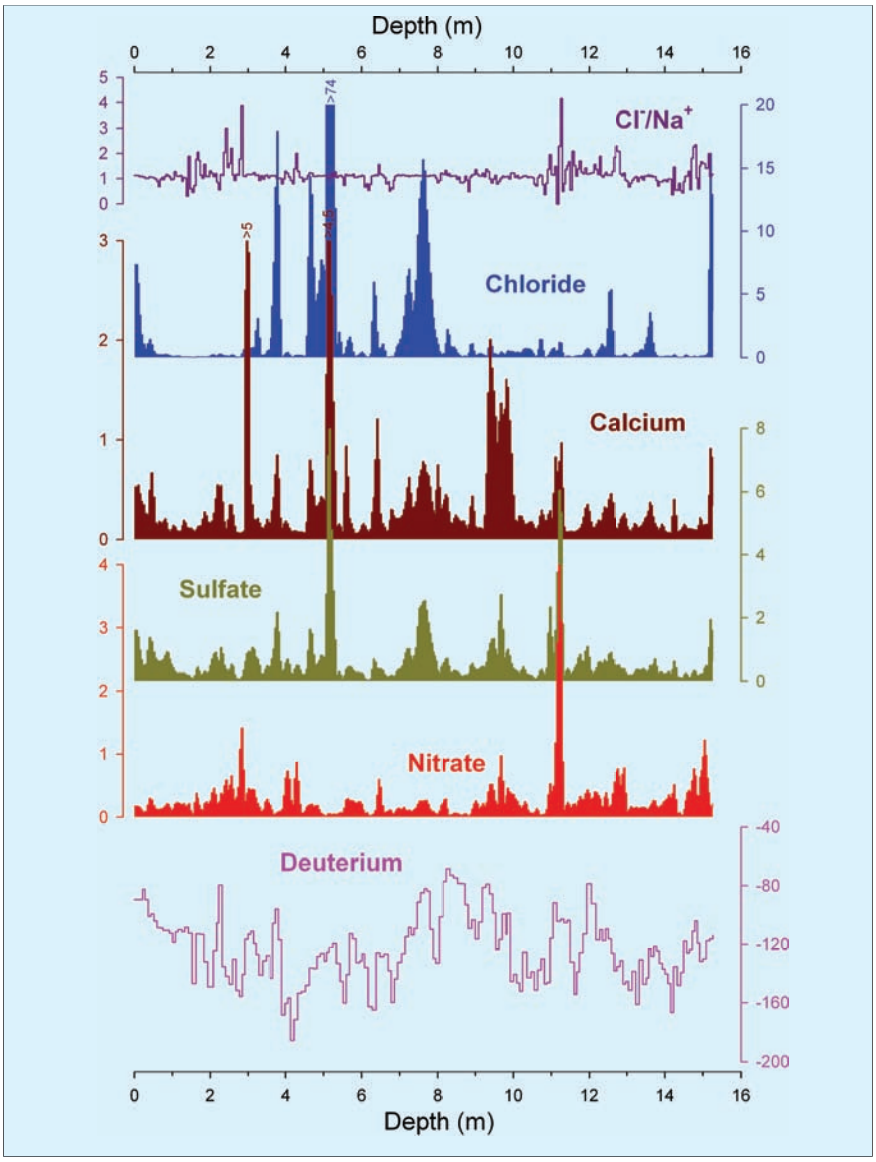

Figure 2: Selected chemical concentration (μEq.L^{-1}), ratio and δD (‰ versus SMOW) profiles measured along the San Valentin 16-m-long shallow ice core extracted in March 2005.

core will be recovered down to the bedrock by IRD Great Ice and its partners on the San Valentin site, and some preliminary investigations performed on the San Lorenzo glacier, about 50 km farther southeast. Ice thickness and estimated accumulation rate on San Valentin allow us to expect paleoclimate reconstructions at high resolution over, at least, the last 2000 years. The deepest part of the ice cores might include the Last Glacial Maximum. Ice will be dispatched to all the participating laboratories. The ice core diameter will permit us to provide enough material to establish all the profiles with the required resolution.

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Sediment, pollen and isotope evidence for an Early to Mid-Holocene humid period in the desert of Yemen

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Introduction

Environmental reconstructions of tropical deserts during the Holocene have mainly focused on Northern Africa. There, numerous lake-level and pollen data have been extensively used for regional reconstruction of past hydrological or vegetation changes, as well as for paleoclimatic models connecting environmental changes with variations in the Earth's orbit or investigating atmosphere-vegetation feedback in the climate system. By contrast, very little is known about the environmental and climate history of Arabia, even though recent discoveries of speleothems in Oman (Fleitmann et al., 2003) have yielded high-resolution oxygen isotope records reflecting variations in the Indian monsoon rainfall during the Holocene. However, the northern penetration of the Indian monsoon inland and its impact on hydrology and vegetation are only poorly understood because of the scarcity of continuous continental sedimentary archives. Here, we present the first continuous record of environment and climate in Southern Arabia, based on sedimentological, mineralogical, pollen and isotope studies of al-Hawa (Yemen) paleolake, which covers the time interval from 12 to 7.5 ka BP.

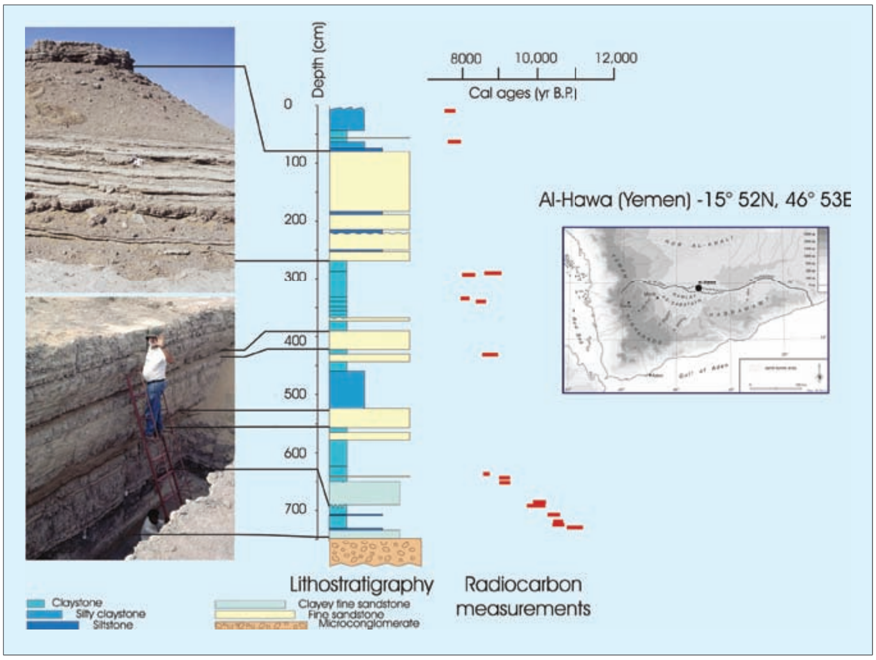

Figure 1: The lacustrine sequence of al-Hawa, Yemen: lithostratigraphy and chronology.

The lacustrine sequence of al-Hawa

The sample site (15°52N, 46°53E, 710 m asl) is a large flat basin located in the inland desert of Yemen, the Ramlat as-Sabatayn, which is the southernmost extension of the Rub al-Khali hyperarid sand sea. The area is surrounded by dunes and fed by wadis, which drain the adjacent Yemen highlands and Hadramawt plateau (Fig. 1). The modern climate is of desert type with annual rainfall of Indian monsoon origin averaging 28 mm, and temperature 27°C at Marib (15°26N, 45°20E). Vegetation is scarce, with trees (*Acacia*, *Commiphora*) confined to wadi channels and highland foothills. Herbaceous plants occur on sand, with *Cyperus* spp., *Calligonum* spp. and *Dipterigyum glaucum* mainly growing on stabilized dunes.

The sediments were discovered in 1993. Following preliminary studies carried out on selected outcrops (Lézine et al., 1998), a pit was dug in 2000 into the lake bed down to a depth of 7.45 m below the top of the sequence. The al-Hawa lacustrine sequence lies on a wadi-type microconglomerate layer with abundant well-rounded centimetric quartz gravels in a sandy matrix. Such facies confirm that a fluvial system connected wadi al-Jawf and wadi Hadramawt before the al-Hawa depression became endoreic during the Holocene (Fig. 1). The lacustrine sequence is mainly composed of massive or finely laminated siltstone, silty mudstone and mudstone with abundant biogenic components, such as molluscs, ostracods, sponges and diatoms. It is interrupted by quartz-rich fine sandstone layers, the most important of which, from 1.75 to 0.75 m, being dated from ca. 8 to 7.7 ka BP.

Concentrations of both authigenic and biologic (molluscs and ostracods) carbonates suggest phases of major lake development peaking between 11-10.5 ka BP (lacustrine phase 1), 10.1-9.1 ka BP (phase 2), 8.4-8 ka BP (phase 3), and 7.8-7.5 ka BP (phase 4) (Fig. 2). Pollen and isotope data from freshwater shells show that the paleolake of al-Hawa was formed in a very arid environment: high percentages of Amaranthaceae/Chenopodiaceae and high values of $\delta^{18}O$ (+4.18‰) indicate saline and highly evaporated conditions. Such high $\delta^{18}O$ values are observed today in dry areas of North Africa, at Lake Chad, Lake Abhé or Lake Awassa, while Amaranthaceae-Chenopodiaceae pollen types dominate in salty places in the desert. Conversely, the intermediate levels record negative $\delta^{18}O$ values, averaging -4.6‰, close to the characteristically low $\delta^{18}O$ of monsoonal rainfall, suggesting that the isotopic composition of precipitation was controlled by the amount of rain falling over the core site. The increase in percentages of fern spores and *Typha* confirms the humid conditions and points to the extension of reed swamp populations at the lake shore during the same time interval. The uppermost levels of the al-Hawa sequence indicate the return to dry conditions at ca. 7.5 ka BP responsible for the subsequent drying out of the al-Hawa lake.

Regional vegetation

Up to 91 pollen and fern spore taxa have been recorded in the sediment. They belong to three clearly distinct phytogeographical groupings: Tree taxa are mainly of Somalia-Masai (*Acacia, Commiphora, Maerua, Salvadora persica*), and Afro-Montane (*Olea, Juniperus, Myrica, Podocarpus, Ephedra, Acacia, Dodonaea viscosa, Rhus, Celtis*) origin and belong to sclerophilous woodlands and scrubs. All these taxa are found in modern Yemen, except *Podocarpus*, for which the nearest pollen source is the East African highlands. Herbaceous pollen taxa are of Saharo-Sindian origin, with modern distribution in the deserts of Rub al'Khali and Ramlat as-Sabatayn. Pollen spectra are dominated by herbaceous taxa, mainly Poaceae, Cyperaceae, Cichoriae, Amaranthaceae/Chenopodiaceae, *Typha* and ferns. Tree pollen grains are scarce, never reaching percentages higher than 13%. This points to the permanency of a semi-arid landscape in the al-Hawa basin during the early to mid-Holocene.

Hydrological changes and rainfall variability

The al-Hawa record shows that, during the Holocene, Southern Arabian hydrology was very sensitive to both orbitally induced monsoon variations and other, superimposed, centennial- to millennial-scale variations of the global climate system. It is consistent with the nearby speleothem record from Oman (Fleitmann et al., 2003), which shows that the summer monsoon influence increased significantly after 10.3 ka BP and decreased after 7 ka BP in response to the north-south movements of the Intertropical Convergence Zone (ITCZ) over the Arabian peninsula. Our data sug-

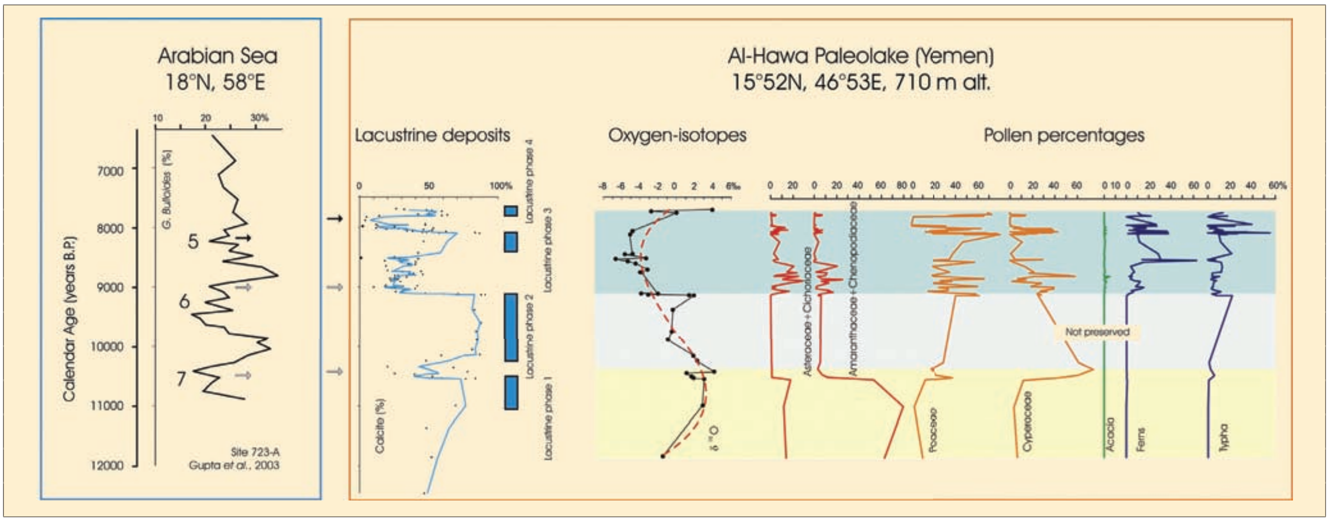

*Figure 2: The "Arabian Humid Period" from marine and continental archives. **Left panel**: Globigerina bulloides percentages from ODP site 723 (Gupta et al., 2003) with highest percentages reflecting phases of strong upwelling in the Arabian sea. Numbers refer to Bond events (Bond et al., 1997). **Right panel**: the lacustrine record of al-Hawa (Yemen) with three "dry" events punctuating the humid period (arrows). Pollen data and the oxygen-isotope record on fresh-water shells shows the dramatic increase in summer monsoon rains from 9000 yrs B.P. onwards. Arid, evaporated, conditions increased toward the end of the "Arabian Humid Period", and the al-Hawa lake completely dried out at 7500 yrs B.P.*

gest that the ITCZ reached the core site (16°N) from 9 ka BP onwards. In addition, the abrupt climate variations recorded from ice and ocean cores during the Holocene (Bond et al., 1997) have also been recorded in Southern Arabia, by a succession of dry phases, between 10.5-10.1, 9.1-8.4, and 8-7.8 ka BP, thus confirming previous observations on the Indian monsoon system from the adjacent ocean (Gupta et al., 2003).

Conclusion

The al-Hawa sedimentary sequence provides an exceptional, and rare, continuous record of environment and climate variations in the Southern Arabian Desert. Paleolake records are surprisingly scarce in this region (Lézine et al., in press). Al-Hawa, as with many of the other freshwater extensions in the Rub al'Khali desert, benefited from surficial runoff from the adjacent highlands located to the south (the Hadramawt plateaus) and to the west (the Yemen highlands). The flat morphology of its wide basin made it very sensitive to low amplitude variations in rainfall. The presence of the Hadramawt plateaus and the Yemen highlands, which acted as topographical and ecological barriers against the northward penetration of tropical plants (as observed in the Saharan desert at that time), played a determinant role in the vegetation composition, which remained of desert, semi-desert type throughout the Holocene humid period.

Note

The presented data is available in the MEDIAS database at: medias.obs-mip.fr/eclipse

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A better climate for human evolution

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Investigations of both terrestrial and marine paleoclimate archives have resulted in an ongoing debate concerning global vs. local climate forcing and associated environmental changes in East Africa. A better knowledge of shifts between dry and humid conditions is key to our understanding of processes influencing mammalian and, in particular, hominin evolution (deMenocal, 1995; Trauth et al., 2003, 2005). Because of the unique tectonic and magmatic evolution of the East African Rift System (EARS) and resulting changes in orography and drainage patterns, terrestrial paleoclimate records from these environments may not always automatically reflect the environmental changes inferred from marine records. For example, the tectonic and magmatic evolution of the EARS has resulted in highly variable sedimentary environments in close proximity to each other, whose depositional record may be fundamentally influenced by local conditions rather than global signals. Thus, it is important to strive