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Fouara (Western Rif, Morocco)

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Site details

The temporary pond of Fouara (35°1' 51" N, 5°12' 7"W) is located at the foothills of the northern slopes of Jbel Khesana (western Rif Mountains) at approximately 1040 m above sea level (a.s.l.), 4 km south of Bab Taza (Chaouen). This mountain range consists mainly of Early to Late Cretaceous flysch facies, with sandstones in the upper area (Service Géologique du Maroc 1980). The Bab Taza weather station (818 m a.s.l.) records a mean annual temperature of 19.2°C, and mean annual rainfall reaches 1104 mm.

The study area is within the subhumid bioclimatic range in the Mesomediterranean belt (Benabid 1984). The vegetation at this altitude is mainly composed of *Quercus suber* L. forests, with a significant presence of other oaks (*Quercus ilex* L. and *Quercus faginea* Lam.), *Erica arborea* L., *Arbutus unedo* L., *Cytisus villosus* Pourr. and *Cistus populifolius* L. Above, the oak forests of *Quercus pyrenaica* Willd. cover the north-facing slopes. The mire vegetation mainly comprises of Cyperaceae, like *Eleocharis palustris* (L.) Roem. Et Schult., Poaceae, including *Glyceria spicata* Guss., Juncaceae, such as *Juncus heterophyllus* Dufour, as well as *Ranunculus* L. spp. and *Isoetes velata* A. Braun.

Sediment description

A 350-cm core was collected in 2014 using a 5-cm diameter Russian corer. The sediment composition of the core is as follows:

- 0–80 cm: light brown peat with herbaceous detritus
- 80–145 cm: darker brown decomposed peat with grey silt
- 145–185 cm: lighter brown peat with light clay
- 185–200 cm: grey silt
- 200–218 cm: darker grey silt
- 218–239 cm: lighter grey silt
- 239–242 cm: darker grey silt
- 242–270 cm: lighter grey silt with light brown clay
- 270–338 cm: darker grey silt with gravels
- 338–350 cm: light brown clay with gravels and sands

Dating

Accelerator mass spectrometry (AMS) carbon-14 dating was performed by the Poznań Radiocarbon Laboratory (Poland) on bulk peat samples and provided the following ages:

- 90 cm: Poz-46708, 670 ± 50 BP (553–679 cal. BP, median probability: 627 cal. BP)
- 197 cm: Poz-46710, 1600 ± 35 BP (1398–1538 cal. BP, median probability: 1471 cal. BP)
- 206 cm: Poz-46711, 1680 ± 30 BP (1518–1624 cal. BP, median probability: 1571 cal. BP)
- 239 cm: Poz-46712, 2700 ± 35 BP (2752–2861 cal. BP, median probability: 2804 cal. BP)
- 303 cm: Poz-46714, 3120 ± 35 BP (3233–3402 cal. BP, median probability: 3341 cal. BP)

Interpretation

The core was sub-sampled at 1-cm intervals. The pollen content of a total of 53 samples was analysed. More than 500 terrestrial pollen grains were identified in each sample, except in samples 117–133 which were considered as sterile. The pollen sum (100%) includes all pollen grains except those of Cyperaceae, spores of ferns, and non-pollen palynomorphs (NPP). Four local pollen assemblage subzones were defined using CONISS in the TGVIEW® (© Eric C. Grimm) software package (Figure 1).

The main pollen zone FOUA (FOUA1, FOUA2 and FOUA3), between 3580 and 900 cal BP, shows a wide dominance of deciduous oaks. This pollen type includes *Q. suber*, *Q. faginea* and *Q. pyrenaica* Willd. In addition, cedar pollen grains also appears with significant percentages. By contrast, FOUB (between 900 cal BP and today) displays a dramatic depletion of oak forests in parallel with a sharp increase in herbaceous taxa, likely related to a hydrological change in the study area. In parallel, cedar pollen virtually disappears.

FOUA1 (349–227 cm; c. 3580–2215 cal BP)

Subzone FOUA1 is characterised by the highest percentage of *Cedrus* Trew, confirming its presence at the altitude of Fouara 3500 years ago, pointing to mixed forests with deciduous oaks, which would dominate the tree landscape along with evergreen oaks. Currently, Atlas cedar is only found at elevations greater than 1400 m a.s.l. in the Rif Mountains. The low percentages of both shrubs (e.g. *Cytisus* Desf.) and herbs (e.g. Poaceae) suggest relatively dense forests. The maximum values of aquatic taxa such as *Myriophyllum* L. and *Ranunculus* L. might indicate a marked seasonality, causing the pond to dry up in the summer, against the low levels of the permanent water indicator species, such as *Botryococcus* Kützing or *Spirogyra* Link. The parallel higher percentages of deciduous oak and decreasing values of *Cedrus* pollen in FOUA1 also denote increasing aridity, which would have promoted the expansion of oak forests as well as the upward migration of *Cedrus* forests (Cheddadi et al. 2017; Abel-Schaad et al. 2018). Moreover, the sporadic occurrences of nitrophilous herbs and spores of coprophilous fungi such as *Sordaria* Ces. et De Not. (HdV 55) or *Sporormiella* Ellis et Everh. (HdV 113) suggest a limited human impact on the ecosystems.

FOUA2 (227–183 cm; c. 2215–1310 cal BP)

Arid climatic conditions seem to remain, despite references to a very wet period (Martín-Puertas et al., 2010), favouring a further spread of deciduous oaks to their maxima as well as a decrease in the percentage of *Cedrus*. In addition to the upward migration of cedar forests (Abel-Schaad et al., 2018), human activities enhance their imprints, not only shown by coprophilous fungi (*Sordaria*, *Sporormiella* and *Cercophora* Fuckel) but also by the occurrences of *Cerealia*. Their impact seems to have been specifically more severe on Poaceae, whose area could have been used both for cultivation and pastureland.

FOUA3 (183–145 cm; c. 1310–900 cal BP)

A first marked decline in forests, mainly represented by oak, coupled with a sharp increase in Poaceae and nitrophilous herbs like *Anthemis* L., *Aster* L., Cardueae, Cichorioideae, *Plantago* L. as well as ferns like *Pteridium* Gled. ex Scop., suggest an opening of landscape related both to the increasing aridity, which defines the Medieval Climatic Anomaly (Martín-Puertas et al., 2010), and the impact of human activities through specifically cereal cultivation. This open forest would have favoured the arrival of cedar pollen in the wetland, as indicated by the slight increase in its percentages. The presence of *Pseudoschizaea circula* (Wolff) Christopher attests the occurrence of erosive processes despite the final recovery of forests.

FOUB (145–0 cm; c. 900 cal BP- present)

Arboreal pollen reaches its minima. *Cedrus* virtually disappears from the pollen record whereas oak forests maintain low pollen percentages. The decrease in cedar pollen percentages could be related to the upward migration of cedar populations in search of more suitable habitats, as described for other records located at higher altitudes in the Jbel Khesana (Cheddadi et al., 2015; Abel-Schaad et al., 2018). Shrub taxa, specifically *Cistus* L., *Erica* L. and *Helianthemum* Mill. show significant percentages. By contrast, herbaceous taxa obtain their maxima, especially in Poaceae, but also nitrophilous taxa such as *Aster*, Cardueae, Chenopodiaceae, Cichorioideae or *Plantago*. This sharp change indicates the widespread of human activities, as also shown by the occurrences of *Cerealia*, *Vicia faba* L. and *Sporormiella*. Additionally, the

climate seems to be warmer and dryer, as indicated by the high values of *Isoetes* L., which can be related to an earlier desiccation of the temporary pond (Molina et al., 2009) as well as the increasing levels of Cyperaceae and HdV 16, the latter indicating dry phases (Van Geel and Aptroot, 2006). Both increased human impact and a warmer and dryer climate were likely the main drivers of the final demise of cedar forests.

Disclosure statement

No potential conflict of interest was reported by the authors.

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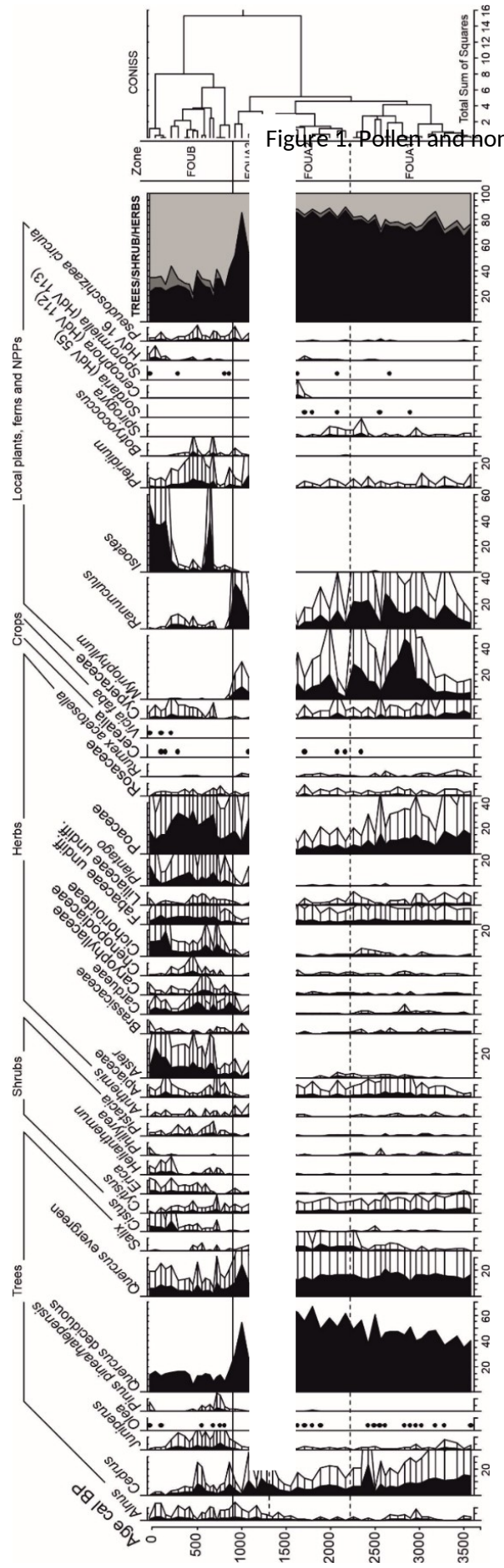


Figure 1. Pollen and non-pollen palaeobotany