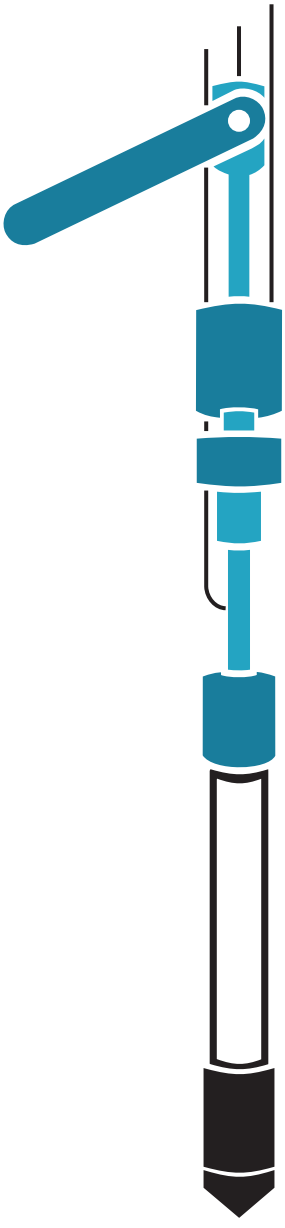
Digging deep

Engaged in a project of longstanding and far-reaching relevance, **Dr William Fletcher** reveals his diverse passions in the field of Physical Geography and discusses his current research into the prehistoric impacts of abrupt climate change in the Middle Atlas region of Morocco



Could you begin with an insight into your background in palaeoclimatology? What ignited your passion in this field?

I have a broad background, having studied archaeology as an undergraduate, and my first independent research experience involved identifying wood charcoal fragments from prehistoric caves. My fascination for the signals of environmental and climatic change contained in this fossil material led me towards palynology, the study of ancient pollen and spores. Ecological records from unlikely places provide a window into the factors behind past climate change.

What drew you to focus on Holocene environmental change?

The Holocene epoch – the 11,700 years or so since the end of the last glacial – was for a long time thought of as very stable; almost boring, in terms of climatic change. However, recent research has brought to light how variable the Holocene climate was and much work has been devoted to elucidating the timing and nature of those changes. For example, during the early Holocene, a number of high latitude cooling events have been documented, associated with arid events in the Mediterranean region. However, many details of the regional extent and impact of such events are still unknown.

The Holocene also represents the period in which humans have become a dominant influence on the Earth System. So I'm interested in tracing the early impacts of human activity; distinguishing human influence from natural factors in environmental change.

Can you outline the scientific basis and aims of your current research?

Lake basins steadily accumulate sediments over long periods of time, and so represent an archive of conditions within the lake system, and in the surrounding region thanks to dust, pollen or charcoal transported from beyond. Today, a wide suite of techniques can be used to examine the characteristics of the sediments and their fossil content, providing detailed records of environmental change.

We focus on producing new vegetation records by studying ancient pollen, and past fire regime records by quantifying charcoal fragments in the sediments. The specific aim is to develop records with high temporal resolution for the period corresponding to the end of the last glacial period and transition into the early Holocene. We know that multiple abrupt climate change events occurred during these intervals, but detailed knowledge of their impact remains poor. Ultimately, we'll need a global network of detailed records to understand the nature, causes and consequences of such events.

Cores and effects

An international palaeoclimatology collaboration based at the **University of Manchester**, is utilising data from new deep lake core samples to understand the prehistoric effects of climate change

HOW BEST TO respond to global climate change is arguably one of the most important and divisive issues ever to be faced by humankind. Following the Intergovernmental Panel on Climate Change's (IPCC) recent report, which – despite an apparent plateau in the upward trajectory of average global surface temperatures – focuses on the most recent tranche of evidence confirming the anthropogenic nature of the global warming phenomenon, the rampant politicisation of this issue continues apace, and severely polarised opinions dominate public debate. The 'climate sceptics' – a vocal minority whose opposition to the scientific consensus is amplified by the backing of vested interests – make a valid point; there remains a great deal to understand about the global climate system and its historical fluctuations. On a global level, climate scientists are working to rectify this situation, devising new ways to fill the gaps in our knowledge using robust empirical data.

The field of palaeoclimatology makes important contributions to enhancing our ability to distinguish anthropogenic from natural effects. Taking the entire history of the planet as its temporal context, the goal of this area of study is to build up a detailed picture of the changing conditions in each of the world's climate regions over time, collating and cross referencing data from a range of sources to uncover the complex interplay between various environmental causes of, and ecosystem responses to, historic climate change. Concepts behind the main proxy methods used, such as tree ring analysis – dendroclimatology – or drilling for ice cores in the planet's polar regions to glean the data preserved there within the layers of permafrost, are well known.

Perhaps less widely recognised is the potential contribution of palynology to the veracity of our general palaeoclimatological overview. Dr William Fletcher from the University of Manchester, UK has expertise in palaeoclimatology and palynology and, as Principal Investigator of the 'Impacts of abrupt glacial and deglacial climate events on vegetation and fire regime in the Middle Atlas, Morocco' project, he is incorporating sedimentological, palaeolimnological, palaeohydrological and geochemical investigations with a view to advancing the understanding of climate-vegetation-fire interactions in the Mediterranean region.

THE PERFECT LOCATION

Largely funded by the German Science Foundation (DFG), and in consultation with the Moroccan National Institute of Archaeological Sciences and Heritage (INSAP), an expedition was launched in 2012 to obtain new lake sediment cores from sites in the Middle Atlas mountains of Morocco. Focusing on the main site at Lake Sidi Ali, an international team from the universities of Leipzig, Manchester, Potsdam, Osnabruck and Ghent spent several weeks in Morocco, using UWITEC core sampling equipment to recover long cores from the deeper southwestern part of the lake and a shallower sub basin. The researchers conducted detailed seismic sub bottom sediment profiling surveys to determine the best coring sites, and during the same trip, seismic surveys and short core sampling of three other Atlas lake sites were also conducted in preparation for the next round of drilling outlined in the project proposal.

The wealth of information extracted from these terrestrial core samples through

The Middle Atlas represents an ideal location for testing hypotheses about the environmental responses to climate change; although palaeoenvironmental research had previously been conducted there in the 1980s and 1990s, this had not been followed up extensively, so there was great potential to return to the Middle Atlas lakes to build informative new records. Given the intensity of current interest in rapid climate change, the questions themselves have inevitably evolved since the time of earlier research.

What expertise is contributed by your partnerships?

International partnerships are key in this project, both in terms of cooperation in the field and in bringing together a range of expertise to better interpret the new records. Two collaborations are particularly vital: the 2012 coring expedition was coordinated by Christoph Zielhofer of Leipzig University, a geomorphologist and sedimentologist with extensive knowlede of North Africa and the Near East, and Potsdam University's Steffen Mischke – a palaeohydrologist specialising in the study of Eurasian lake systems who is an expert in the identification of ostracods (small, shelled crustaceans). Overall, the great benefit is the ability to compare and contrast the record of ecosystem changes with independent signals of hydrological change in the lake system, and with geomorphological instability in the catchment. The logistical support and regional knowledge of Abdeslam Mikdad (INSAP) was also invaluable to the expedition.

With extensive experience working in international collaborative projects, for you, what is the importance of collaboration in research?

Collaboration has many benefits. On an intellectual level, it is about tackling problems from more than one standpoint. In an age where scientists are typically highly specialised, this allows people to bring a range of knowledge to the table. On a practical level, collaboration can help to bring ideas to reality, making things financially or logistically possible which were previously unthinkable, and to maintain the momentum and lateral thinking needed to push through setbacks.

IMPACTS OF ABRUPT GLACIAL AND DEGLACIAL CLIMATE EVENTS ON VEGETATION AND FIRE REGIME IN THE MIDDLE ATLAS, MOROCCO

OBJECTIVES

To advance the understanding of climate-vegetation-fire interactions in the Mediterranean region and the sensitivity of montane ecosystems to abrupt climate forcing.

KEY COLLABORATORS

Professor Dr Christoph Zielhofer, Leipzig University, Germany • **Professor Dr Steffen Mischke**, Potsdam University, Germany • **Professor Dr Abdeslam Mikdad**, National Institute of Archaeological Sciences and Heritage (INSAP), Morocco

FUNDING

The Natural Environment Research Council (NERC) – New Investigator Award

The German Science Foundation (DFG)

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DR WILLIAM FLETCHER has expertise in fields such as palynology, palaeoecology and palaeoclimatology. He was appointed lecturer in Physical Geography and Quaternary Science at the University of Manchester, UK in 2010, following completion of his PhD at the University of Cambridge, UK and postdoctoral research positions at Bordeaux I University in France and Goethe University Frankfurt, Germany.

palynology provides a great deal of scope for understanding the sensitivity of montane landscapes to abrupt climate changes, at a level of chronological resolution not previously possible. This is important work, as it is known that mountainous regions and the human populations who inhabit them are particularly vulnerable to the effects of rapid climate change. Increased risk of flooding and forest fires, as well as deforestation and soil erosion, are associated with the increased severity of droughts and heat waves accompanying sudden changes in temperature and hydrological regimes. Current climate models suggest that many such changes await the Western Mediterranean in the coming century, so a greater understanding of the region's prehistoric climate-vegetation-fire interactions will be vital in responding to these challenges.

Located at the interface of mid-latitude and subtropical climate systems, the Middle Atlas region of Northwest Africa is a prime location for understanding the characteristics of climatic events over the last glacial and deglacial periods, extending into the early Holocene beginning some 11,700 years ago. Overseen by Fletcher at the University of Manchester with funding from the Natural Environment Research Council (NERC), high-resolution analyses of the samples' pollen and charcoal content are underway, enabling the development of centennial-scale records of vegetation dynamics for the period. Radiometric dating techniques are producing robust chronologies for these sediment sequences, independently establishing the timing of key changes during the last 25,000 years.

CROSS REFERENCING CHRONOLOGIES

Despite some major challenges – such as the difficulty of excluding so called reservoir effects (the influence of older carbon) from the dating results, and unexpectedly scarce plant macroremains in some of the samples – early results suggest significant centennial- and millennial-scale variability in the regional climate, linked to shifting air mass trajectories over the mountainous landscape. With the support of the NERC Radiocarbon Facility at East Kilbride, Fletcher is developing a suitable methodology for dating the pollen grains themselves. By determining the relative diversity and abundance of these ancient pollen morphotypes, which correspond to different taxonomic groups of plants, changes in the region's vegetation cover and composition can be plotted over time, while quantifying the microcharcoal deposits in the same samples allows the role of fire regime in the local ecosystem to be factored into the overall picture.

> Study of the Mediterranean region presents significant opportunities for understanding the resilience of regional ecosystems in the face of rapid climate change

Insights offered by this project will add to recent advances made by the adoption of the land sea correlation approach to studying abrupt glacial and deglacial climate changes. For example, the study of pollen in marine cores from the Alboran Sea some 300 km north of the Middle Atlas indicates shifts in western Mediterranean vegetation cover in response to such changes, but it has hitherto been difficult to elucidate how the impact may have varied in different environmental settings. This is because the marine cores cover a vast catchment area and in analysing them alone the proportional contribution of North African and southern Iberian pollen is impossible to measure. This renders the separation of climatic influences on pollen pathways to the sea from impacts on regional vegetation problematic. However, due to the fact that the North African species *Cedrus atlantica* (the Atlantic Cedar so emblematic of the Middle Atlas region) can be safely identified in the marine cores, comparative analysis of the lake cores will answer questions regarding the provenance of such taxa.

As a biodiversity hotspot likely to face increased heat stress, summer drought and water deficit in the coming century, Fletcher's study of the Mediterranean region presents significant opportunities for understanding the resilience of regional ecosystems in the face of rapid climate change. Greater knowledge of climate dynamics in the recent geological past will improve the accuracy of climate models of the Earth System, representing our best chance of keeping ahead of future scenarios in a rapidly changing world.

Pollen from Middle Atlas lake sediments.

Sidi Ali - archive of regional change.

Sediment coring at 30 m water depth.

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