When the Sahara Grew Green: Constraining the 'Green Sahara' Across Time and Space

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Understanding the dynamics of Earth's ancient climate is an important avenue of research. By examining past climate variability, we can improve our understanding of natural climate cycles and factors influencing current climate change. Dr Yassine Ait Brahim of the University Mohammed VI Polytechnic (UM6P) in Morocco worked with colleagues to analyse isotopic data recovered from cave mineral deposits in Northwest Africa. This exciting research is focused on the precipitation history of the Sahara Desert, which, perhaps astonishingly, had periods of vegetation cover and mega-lakes.

The Sahara Hasn't Always Been a Desert

The Sahara Desert is one of the world's best-known desert ecosystems. It stretches 9.2 million km2 across northern Africa, covering almost 8% of the Earth's land surface. Today, it receives as little as 76 mm of rain per year – although this hasn't always been the case. In the not-so-distant past, the Sahara hosted networks of rivers and mega-lakes, while supporting widespread vegetation. For this reason, these periods of the Sahara's history have been termed the 'Green Sahara'.

The episodes of Sahara greening are thought to have been spurred by changes in Earth's orbital forcing, which are measures of our tilt towards the sun and our orbital path around it. This influences the amount of solar energy, termed solar insolation, reaching Earth's surface. Due to a variety of factors, higher summer insolation leads to intensified monsoon seasons, resulting in increased precipitation. This, coupled with multiple other processes occurring on Earth that influence precipitation patterns – including higher winter precipitation brought by eastward travelling winds (the westerlies) – resulted in a contraction of the North African Sahara Desert, which periodically became lush and green.

Such changes in the hospitability of this important corridor across, and out of Africa, will have had implications for ancient human subsistence and migration patterns, and may have even influenced cultural industries.

Palaeoclimate Data Stored in Cave Minerals

Pinpointing the exact timing of past events is a complex task. Challenges stem from the scarcity of well-dated records, uncertainties in dating methods, and the innate complexity of environmental processes. However, establishing precise chronologies for environmental events holds great significance. A well-constrained understanding of past environmental changes enables us to comprehend how local fauna, including some early human (*Homo sapiens*) populations – termed Anatomically Modern Humans (AMH) – responded to shifting ecological conditions in Africa.

While previous research has identified the Green Sahara periods in northern Africa, the general paucity of precisely dated environmental records hinders the identification of a reliable association between environmental conditions and important advances in human history..

Dr Yassine Ait Brahim of the University Mohammed VI Polytechnic in Morocco explores the spatial and temporal extent of the Green Sahara during the last 80,000 years. By analysing stable isotope ratios from three speleothems (mineral deposits) in the Wintimdouine cave in Morocco, he was able to reconstruct a well-dated, high-resolution climate record which elucidates the environmental conditions across ancient Northwest Africa.

Speleothems include structures such as stalagmites and stalactites. The minerals within these deposits, the source of which Dr Ait Brahim identified as being from rainfall percolating through the cave roof, contain uranium, which, over time, decays into thorium isotopes. The carbonates present in the three speleothems from Wintimdouine cave were dated using Uranium-Thorium methods, revealing how long ago the speleothems were formed. Furthermore, calcite samples, from which oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopes were extracted, were taken from the same three speleothems.

Isotopes can be used as a proxy (indicator) for certain climatic environments. For example, Dr Ait Brahim used oxygen isotopes as a proxy for precipitation levels. Within the cave system, they

were able to correlate the levels of $\delta^{18}O$ with the amount of rainfall and $\delta^{13}C$ with vegetation growth. Due to interactions between atmospheric conditions and the weight of different oxygen isotopes affecting their presence in rainfall, Dr Ait Brahim and his team could infer periods of higher and lower precipitation over the cave system, with $\delta^{18}O$ values presenting an inverse relationship to precipitation levels.

Furthermore, periods of higher vegetation growth deplete soil $\delta^{13}C$, which is mirrored in the $\delta^{13}C$ present in the speleothems. Therefore, by correlating the precisely dated speleothems and environmental proxy data, a reconstruction of precipitation patterns and vegetation growth could be inferred for specific periods in Earth's history. Dr Ait Brahim's data of low $\delta^{18}O$ and $\delta^{13}C$ values indicate a wet, humid climate with widespread vegetation around 84,000–77,000 years ago, a period known as the Marine Oxygen Isotope Stage 5a (MIS 5a), and in the Early to Mid-Holocene (9,000 to 4,000 years ago).

The MIS 5a reconstruction is especially significant, as it is the only palaeoclimate record with such precise dating for Northwest Africa. He compared his data with previously published palaeoclimatic reconstructions, which not only supported his interpretation of a Green Sahara during these periods but also revealed the great extent of the environment, reaching further south and spreading across to Eastern Africa and the Eastern Mediterranean.

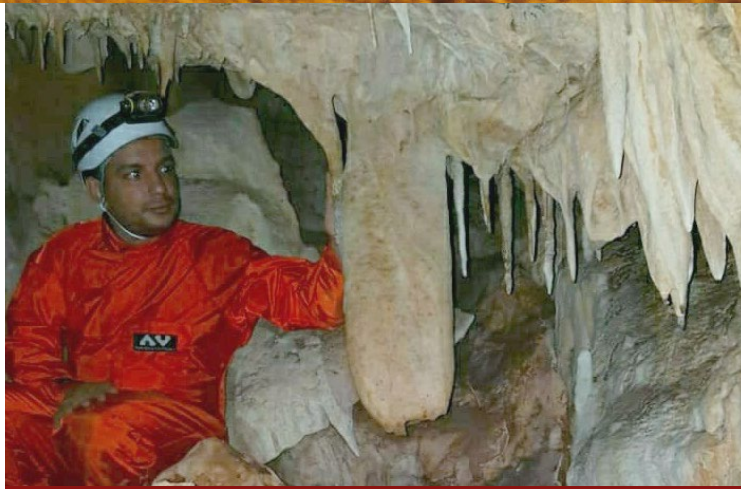
The Grass isn't Always Greener: Human Migration and Cultural Advances

Such changes in palaeoclimate will have had profound and extensive consequences on the surrounding environment in Northwest Africa. During the period that Dr Ait Brahim's study focuses on, AMH populations are thought to have begun their larger-scale migrations out of Africa. The research team highlighted that the Green Sahara likely played a pivotal role in influencing such migrations.

During MIS 5a, the AMH populations, characterised by their stone tool industries, termed the 'Aterian' industry, were widespread across North Africa. However, when rainfall decreased with the transition into the succeeding MIS 4, desert conditions would have expanded, fragmenting AMH populations and pushing them into refugial areas such as coastlines, potentially inciting their migration out of Africa.

These conclusions are supported by archaeological evidence from contemporary sites in Morocco. Shifts in human population densities appear to correlate with palaeoclimatic changes, which peak during favourable periods such as MIS 5a and decline during dry desert conditions of MIS 4. Furthermore, exchange networks of symbolic cultural materials such as beads and pigments, which are noted across both coastal and inland sites, appear to have ceased after MIS 5a, further supporting Dr Ait Brahim's palaeoclimatic results.

Dr Ait Brahim's study fills a crucial gap in our understanding of past environmental changes in North Africa. However, he emphasises the need for further research to improve the precision of archaeological site dates and deepen our understanding of paleoclimate changes. Such research would enhance the applicability of their results to human dispersal models and provide valuable insights into our history.



Credit Yassine Brahim

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MEET THE RESEARCHER

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Dr Yassine Ait-Brahim is a professor specialising in climate science and integrated water resources management. After completing a PhD (2014–2016) at Ibn Zohr University in Morocco, Dr Ait Brahim embarked on collaborative research ventures across Germany, the USA, China, Switzerland, and Canada. Upon returning to Morocco, he progressed to his current position as a professor at the International Water Research Institute (IWRI) at the University Mohammed VI Polytechnic (UM6P). With a rich academic portfolio boasting over 60 peer-reviewed publications, Dr Ait Brahim has mentored numerous undergraduate and postgraduate students, organised impactful international scientific events, and served as a Steering Committee Member and Regional Coordinator in international working groups. Most recently, Dr Ait Brahim has secured significant funding from the Partnership for Research and Innovation in the Mediterranean Area and the Swiss LH-MENA scheme to undertake water and climate research focusing on Morocco and the broader African context.

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PAGES – Past Global Changes

FURTHER READING

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