Understanding new evidence of the impact of climate change in the Early Jurassic Period

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Photo shows Early Jurassic lake sediments (black shales) formed in the Tarim Basin, China. Credit: Oxford Science Blog

Geochemical and biological research offers academics a window into earth history, enabling them to piece together events that occurred before records began. Much of our understanding of past climate change is based on geology, in particular the study of sedimentary rocks deposited in the oceans.

The paper that first recognised and defined Oceanic Anoxic Events

(OAEs), written by Oxford professor Hugh Jenkyns and an American colleague, is considered a seminal contribution to geological history, that led the way to numerous studies on the effects of oxygen starvation in the oceans.

The discovery of organic-rich sediments, often described as black shales, at numerous deep-sea drilling sites during the early 1970s, led to the wider acknowledgement of the oceanic impact of climate change. At certain intervals during the Jurassic era, huge bouts of volcanic activity triggered increased concentrations of atmospheric carbon dioxide. This then caused a knock-on greenhouse effect, raising the sea-surface temperature and reducing oxygen levels in large parts of the ocean.

At the same, oceans benefited from increased nutrient levels, and as a result marine algae and bacteria bloomed. As they died, these organisms were preserved in sediments that formed on the sea floor and over time changed into source rocks for oil. It is these phenomena that illustrate the causes and effects of OAEs.

New research, published in *Nature Geoscience*, has for the first time examined the impact of this type of sediment deposition in lakes. The study demonstrates that lake environments responded in a similar way to climate change, developing the same anoxic conditions as in the oceans.

Led by Earth Sciences post-graduate student Weimu Xu, the work offers insight into how environmental factors have affected lake formation throughout the ages. Weimu and the team studied sediments from one of the largest lakes in Earth history - double the size of England and three times the size of Lake Superior - the largest lake (in surface area) in the world today. This ancient lake formed rapidly in the Sichuan Basin, China, as a result of Toarcian (Early Jurassic) climate change, about 183 million years ago.

Weimu spoke with Science Blog about the study's key findings and what they can tell us about climate change today.

What is the key finding that you would like people to take from this study?

The extreme effects of past climatic changes are not limited exclusively to oceans. By dating the lake sediments to the Early Jurassic (Toarcian) period, we were able to show that large lakes formed and were affected in the same way as oceans during an OAE.

As the climate warmed, the continents experienced increased rainfall, creating lake reservoirs, which essentially acted like mini-oceans. Lake organisms became more abundant, drawing-down massive amounts of carbon dioxide from the atmosphere, which was eventually deposited into sediments. Overtime, these sediments became source rocks for oil.

Lake environments represent their own unique challenges. Did you encounter any specifically?

The biggest challenge for us was establishing the age of the sediments found in the Sichaun Basin, and proving that they were of similar age to those that formed in the oceans during the Toarcian OAE. The wealth of organic matter found in marine environments makes it quite easy to date an event, by basing it on a fossil's geological age. But lakes do not have such fossils, which makes it much harder to determine the age of the sediments found.

A study of this nature involves a massive amount of work. How did you manage such an extensive undertaking?

Fortunately I worked with a great team. This work was led by myself, co-

designed by M. Ruhl, H.C. Jenkyns and S.P. Hesselbo and involved a total of 11 people. The project is a great example of collaborative research.

We used three distinct methodologies, which would be impossible for any one researcher to master. Colleagues from the University of Durham applied radio-isotopic dating to establish the age of the sediments and colleagues from the British Geological Survey studied the pollen, spores and algae preserved in the sediments. Finally, to give us even more detail to support the age of the sediments, together with colleagues from the University of Bristol and at Shell Global Solutions International B.V., we applied stable carbon-isotope to analyse the sediments, plant and algae remains. These varied techniques convincingly showed that the sediments found, had formed at the same time as the Toarcian OAE.

We were fortunate to be able to partner with experts in these three fields, and of course our industrial partner Shell.

How long did the research take to conduct?

The study lasted from the first sampling trip in November 2013 to completion of this manuscript in September 2016. We also had to factor in time to get permission to publish the findings, from the oil companies providing the data.

Are there any long-term impacts associated with your findings?

There are definite links between the climatic event identified in the Toarcian and present-day global warming. A better understanding of past climate systems could help predict environmental and ecological changes in a future greenhouse world. While the lake we studied existed in the

Early Jurassic period, there are lakes today in African and British Columbia for example, that have been affected by global warming. They are becoming more and more anoxic and some are losing fishery stocks as a result. People fixate on warmth, but anoxia goes hand in hand with warmth.

There's a certain irony in the fact that the conditions which created oil and gas deposits millions of years ago are being recreated much more rapidly by burning of these fossil fuels.

How would you like to see this work used in the future?

Our study directly links lake formation and sediment deposition to the Toarcian OAE. By studying other lake sediments that were around at that time, researchers could establish if they also link to this event. For a better understanding of major climatic change in other intervals of the Earth's history, people can also look and see if there were other major lake reservoirs that acted similarly.

It would also be useful to understand the impact, not only of carbon deposition, but carbon burial, during times of major climatic change, and how that impacted coal formation. This is something I am very keen to focus on next.

More information: Weimu Xu et al. Carbon sequestration in an expanded lake system during the Toarcian oceanic anoxic event, *Nature Geoscience* (2017). DOI: 10.1038/ngeo2871

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