Decline of Bronze Age 'megacities' linked to climate change
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Scientists from the University of Cambridge have demonstrated that an abrupt weakening of the summer monsoon affected northwest India 4,100 years ago. The resulting drought coincided with the beginning of the decline of the metropolis-building Indus Civilisation, which spanned present-day Pakistan and India, suggesting that climate change could be why many of the major cities of the civilisation were abandoned.

The research, reported online on 25 February, 2014, in the journal *Geology*, involved the collection of snail shells preserved in the sediments of an ancient lake bed. By analysing the oxygen isotopes in the shells, the scientists were able to tell how much rain fell in the lake where the snails lived thousands of years ago.

The results shed light on a mystery surrounding why the major cities of the Indus Civilisation (also known as the Harappan Civilisation, after Harappa, one of the five cities) were abandoned. Climate change had been suggested as a possible reason for this transformation before but, until now, there has been no direct evidence for climate change in the region where Indus settlements were located.

Moreover, the finding now links the decline of the Indus cities to a documented global scale climate event and its impact on the Old Kingdom in Egypt, the Early Bronze Age civilisations of Greece and Crete, and the Akkadian Empire in Mesopotamia, whose decline has previously been linked to abrupt climate change.

"We think that we now have a really strong indication that a major climate event occurred in the area where a large number of Indus settlements were situated," said Professor David Hodell, from Cambridge's Department of Earth Sciences. "Taken together with other evidence from Meghalaya in northeast India, Oman and the Arabian Sea, our results provide strong evidence for a widespread weakening of the Indian summer monsoon across large parts of India 4,100 years ago."

Hodell together with University of Cambridge archaeologist Dr Cameron Petrie and Gates scholar Dr Yama Dixit collected Melanoides tuberculata snail shells from the sediments of the ancient lake Kotla Dahar in Haryana, India. "As today, the major source of water into the lake throughout the Holocene is likely to have been the summer monsoon," said Dixit. "But we have observed that there was an abrupt change, when the amount of evaporation from the lake exceeded the rainfall – indicative of a drought."

At this time large parts of modern Pakistan and much of western India was home to South Asia's great Bronze Age urban society. As Petrie explained: "The major cities of the Indus civilisation flourished in the mid-late 3rd and early 2nd millennium BC. Large proportions of the population lived in villages, but many people also lived in 'megacities' that were 80 hectares or more in size – roughly the size of 100 football pitches. They engaged in elaborate crafts, extensive local trade and long-ranging trade with regions as far away as the modern-day Middle East. But, by the mid 2nd millennium BC, all of the great urban centres had dramatically reduced in size or been abandoned."

Many possible causes have been suggested, including the claim that major glacier-fed rivers changed their course, dramatically affecting the water supply and the reliant agriculture. It has also been suggested that an increasing population level caused problems, there was invasion and conflict, or that climate change caused a drought that large cities could not withstand long-term.

"We know that there was a clear shift away from large populations living in megacities," said Petrie. "But precisely what happened to the Indus Civilisation has remained a mystery. It is unlikely that there was a single cause, but a climate change
event would have induced a whole host of knock-on
effects.

"We have lacked well-dated local climate data, as
well as dates for when perennial water flowed and
stopped in a number of now abandoned river
channels, and an understanding of the spatial and
temporal relationships between settlements and
their environmental contexts. A lot of the
archaeological debate has really been well-argued
speculation."

The new data, collected with funding from the
Natural Environment Research Council, show a
decreased summer monsoon rainfall at the same
time that archaeological records and radiocarbon
dates suggest the beginning of the Indus de-
urbanisation. From 6,500 to 5,800 years ago, a
deep fresh-water lake existed at Kotla Dahar. The
deep lake transformed to a shallow lake after 5,800
years ago, indicating a weakening of the Indian
summer monsoon. But an abrupt monsoon
weakening occurred 4,100 years ago for 200 years
and the lake became ephemeral after this time.

Until now, the suggestion that climate change might
have had an impact on the Indus Civilisation was
based on data showing a lessening of the monsoon
in Oman and the Arabian Sea, which are both
located at a considerable distance from Indus
Civilisation settlements and at least partly affected
by different weather systems.

Hodell and Dixit used isotope geochemical analysis
of shells as a proxy for tracing the climate history of
the region. Oxygen exists in two forms – the lighter
$^{16}O$ and a heavier $^{18}O$ variant. When water
evaporates from a closed lake (one that is fed by
rainfall and rivers but has no outflow), molecules
containing the lighter isotope evaporate at a faster
rate than those containing the heavier isotopes; at
times of drought, when the evaporation exceeds
rainfall, there is a net increase in the ratio of $^{18}O$ to
$^{16}O$ of the water. Organisms living in the lake
record this ratio when they incorporate oxygen into
the calcium carbonate ($\text{CaCO}_3$) of their shells, and
can therefore be used, in conjunction with
radiocarbon dating, to reconstruct the climate of the
region thousands of years ago.

Speculating on the effect lessening rainfall would
have had on the Indus Civilisation, Petrie said:
"Archaeological records suggest they were masters
of many trades. They used elaborate techniques to
produce a range of extremely impressive craft
products using materials like steatite, carnelian and
gold, and this material was widely distributed within
South Asia, but also internationally. Each city had
substantial fortification walls, civic amenities, craft
workshops and possibly also palaces. Houses were
arranged on wide main streets and narrow
alleyways, and many had their own wells and
drainage systems. Water was clearly an integral
part of urban planning, and was also essential for
supporting the agricultural base.

At around the time we see the evidence for climatic
change, archaeologists have found evidence of
previously maintained streets start to fill with
rubbish, over time there is a reduced sophistication
in the crafts they used, the script that had been
used for several centuries disappears and there
were changes in the location of settlements,
suggesting some degree of demographic shift."

"We estimate that the climate event lasted about
200 years before recovering to the previous
conditions, which we still see today, and we believe
that the civilisation somehow had to cope with this
prolonged period of drought," said Hodell.

The new research is part of a wider joint project led
by the University of Cambridge and Banaras Hindu
University in India, which has been funded by the
British Council UK-India Education and Research
Initiative to investigate the archaeology, river
systems and climate of north-west India using a
combination of archaeology and geoscience. The
multidisciplinary project hopes to provide new
understanding of the relationships between humans
and their environment, and also involves
researchers at Imperial College London, the
University of Oxford, the Indian Institute of
Technology Kanpur and the Uttar Pradesh State
Archaeology Department.

"It is essential to understand the link between
human settlement, water resources and landscape
in antiquity, and this research is an important step
in that direction," explained Petrie. "We hope that
this will hold lessons for us as we seek to find means of dealing with climate change in our own and future generations."

Provided by University of Cambridge