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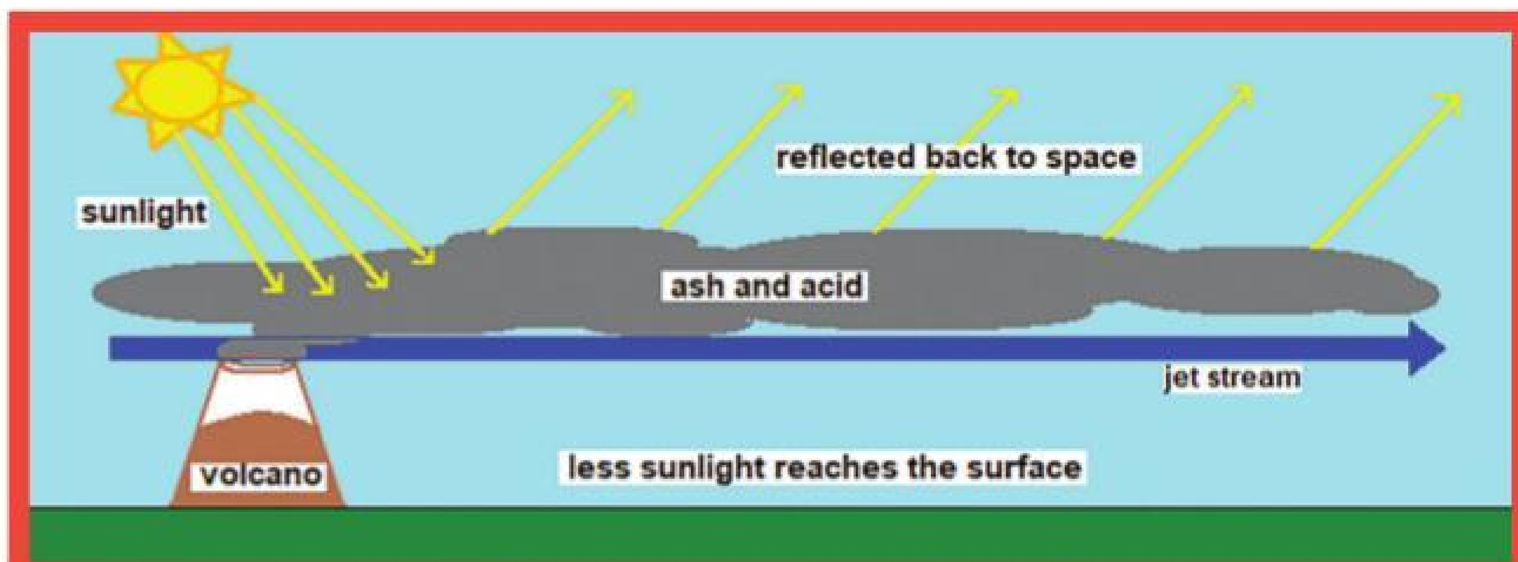
Climate change & the course of history



Climate research has shown how volcanic eruptions triggered the collapse of dynasties

Column of gas and ash rising from Mt Pinatubo in the Philippines

S ANANTHANARAYANAN

While features like mountains and rivers give shape to geopolitics, changes in the climate can be powerful influencers too. The world's responses to the current crisis, of global warming, has created several uncertainties. There could be major changes in the global political pecking order within a few decades.

Social and cultural mores are shaped by climate, the harshness of summers or winters, for instance, or the level of rainfall. And changes in the climate lead to social responses. An instance is how the profile of rooftops in China grew sharper or shallower as the extent of snowfall varied over the seasons.

Another example is the vast Iron Age empire, the neo-Assyrian, in Mesopotamia, which rose to great heights in the three centuries from 911 BCE to 609 BCE, a period of ample rainfall, compared to past millennia. But when mega droughts struck in the seventh century BCE, the empire declined rapidly, making way for the neo-Babylonian empire, over a short 60 years.

A group of researchers writing in the journal, *Nature Communications*, use state-of-the-art methods to identify severe, short-term climate effects of volcanic eruptions, over two millennia of Chinese history. And by matching the events with political history, the team of Chaochao Gao, Francis Ludlow, John A Matthews, Alexander R Stine, Alan Robock, Yuqing Pan, Richard Breen, Brianán Nolan and Michael Sigl, from Zhejiang University, Hangzhou, China, Trinity College Dublin, San Francisco State University, Rutgers University, Florida State University, Rachel Carson Center for Environment and Society, Munich and University of Bern, Switzerland , discover "a systematic association" between the eruptions and instances of dynastic collapse.

Enquiry into how far climatic events have influenced societal decay, the paper says, has been limited because the evidence, both of climate events and social changes in past periods, is at best approximate. In the case of China, however, there are reliable records of the fortunes of a sizeable number of dynasties, 68, in fact, over the first 2,000 years CE. And this record, of long reigns with numerous dynastic changes, presents an opportunity to see if there could be a correlation with changes in the climate.

Many cases of the end of a dynasty have been described as a "collapse", clearly because the end was abrupt and accompanied by a military debacle, loss of lives and economic distress. But there are others, the paper says, where the process was gradual, and the reason for decline has often been stated as rising corruption and dissipation, and general mismanagement. And there are instances where climatic events, like droughts and extreme cold have been linked, and cases where volcanic eruptions could have led to climatic change and the collapse. These, however, the paper says, are episodic and it has not been possible to find a thread that shows that volcanic activity, and resulting climatic effects, have generally gone before the downfall of a dynasty.

Volcanic eruptions, the paper says, "are one of the most important drivers of sudden and pronounced short-term climatic variability." The particulate matter that fills the atmosphere, over a wide region above the eruption, for months, or even years, on end, has two immediate effects. The particles reflect and scatter sunlight, leading to dark days and cooling. And then, the evaporation from water bodies is reduced.

The cycle of moisture-laden air masses is hence disrupted, and rainfall becomes scanty. And the result is that there are lower temperatures and there is drought, during the agricultural growing season. And the impact is compounded by livestock death, which gets worse with degradation of the land. And a consequence of volcano activity in the tropics is that there are mild winters. This promotes the survival of pests, which leads to further damage to crops.

Agronomy was critical to the populous Chinese dynasties. Sudden climate change and extreme weather could hence disrupt economic and political equations. There could be shortages and displacement of populations, and cascading pressures that would topple the delicate balance that sustained royalty. The "mandate from heaven", the authority of the dynasty to rule, was called in question and the stage was set for rivals to move in, and a new order to take over.

The team of researchers scoured a great many historical sources to establish a timeline of the dynasties that held power in China during the first two millennia CE. It was important to fix the dates accurately, the paper says, for successful linking of political events with geological records of volcanic events. Hence the need to examine several historical accounts -- to reduce the uncertainty which often crept in.

Volcanic activity

The record of volcanic activity through the two millennia was extracted from geological evidence. Volcanic events throw up huge quantities of ash, dust and particles, and if the events are powerful, as would be the events that affected the fortunes of dynasties, the material could travel round the globe. The material would then settle as deposits on ice surfaces in different parts of the world.

And the deposits are covered by fresh snowfall and trapped. Ice sheets or glaciers form by incremental build-up of annual layers. Lower layers are thus older than layers closer to the surface and the ice mass is a record of deposits collected over centuries.

The way to extract the information buried in the ice is to bore into it using a shell, with an arrangement to bring up samples of ice from different depths. The drills can go down to over three kilometres, where the samples of ice are 800,000 years old. The team relied on borings in Greenland and Antarctic ice and identified years of volcanic activity when sulphate deposits were detected.

They were then able to identify and date 158 instances of major volcanic eruptions in the northern hemisphere, between the years 1 CE and 1915 CE.

Whether volcanic events were associated with dynastic collapse was then examined by plotting the frequency of volcanic events within the window from 10 years preceding to two years after an instance of dynastic collapse. This 12-year window takes into account the uncertainty in the dates of the volcanic and political events, and also the lag that there would be before there is social response to a climate event.

The result of this survey was that "one or more eruptions preceded the majority (62 out of 68) collapses." To make sure that this apparently high association is not something arising from chance, the data was subjected to statistical analysis, taking the average frequency of eruptions observed in the "collapse windows" and the probability of these eruptions occurring by chance. The analysis, the paper says, established the association with an assurance between 99 and 99.95 per cent.

This remarkable association underscores the fragility of political equilibrium and the strong leverage that climate change can exert. The record studied is of rapid changes at a time of slower communications and mobility. In our current crisis, we have been warned for some decades, but we have the capability to adapt and mitigate the threat. And the stakes, if we do not respond, are higher, not just political change, but environmental collapse as well.

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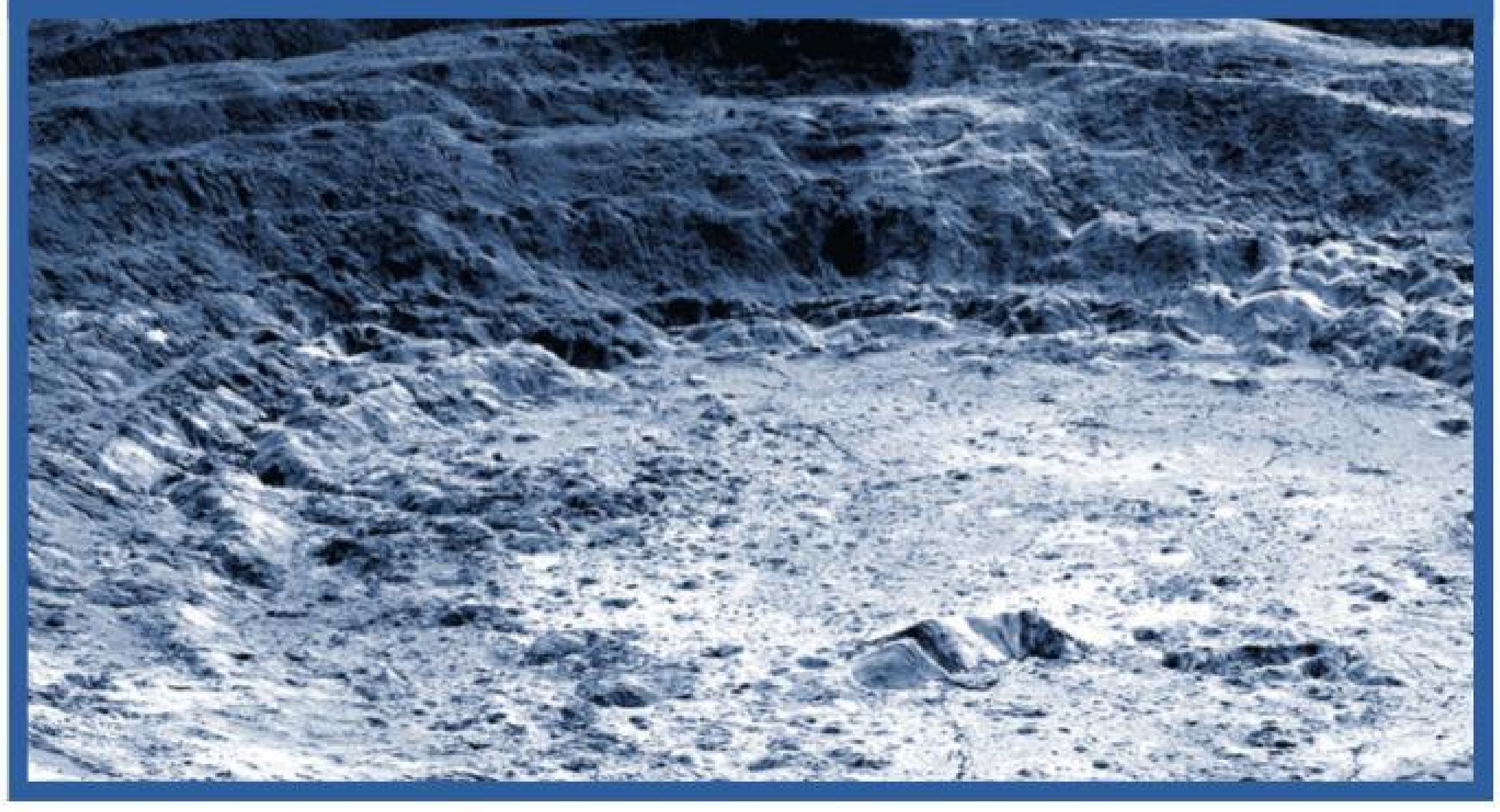
MORE THAN ENOUGH

The Moon's top layer alone has enough oxygen to sustain eight billion people for 100,000 years



JOHN GRANT

Alongside advances in space exploration, we've recently seen much time and money invested into technologies that could allow effective space resource utilisation. And at the forefront of these efforts has been a laser-sharp focus on finding the best way to produce oxygen on the Moon.

In October, the Australian Space Agency and National Aeronautics and Space Administration signed a deal to send an Australian-made rover to the Moon under the Artemis programme, with a goal to collect lunar rocks that could ultimately provide breathable oxygen on the Moon.

Although the Moon does have an atmosphere, it's very thin and composed mostly of hydrogen, neon and argon. It's not the sort of gaseous mixture that could sustain oxygen-dependent mammals such as humans.

That said, there is actually plenty of oxygen on the Moon. It just isn't in a gaseous form. Instead it's trapped inside regolith — the layer of rock and fine dust that covers the Moon's surface. If we could extract oxygen from regolith, would it be enough to support human life on the Moon?

The breadth of oxygen

Oxygen can be found in many of the minerals in the ground around us. And the Moon is mostly made of the same rocks you'll find on Earth (although with a slightly greater amount of material that came from meteors).

Minerals such as silica, aluminium, and iron and magnesium oxides dominate the Moon's landscape. All these minerals contain oxygen, but not in a form our lungs can access.

On the Moon these minerals exist in a few different forms including hard rock, dust, gravel and stones covering the surface. This material has resulted from the impacts of meteorites crashing into the lunar surface over countless millennia.

Some people call the Moon's surface layer lunar "soil", but as a soil scientist I'm hesitant to use this term. Soil as we know it is pretty magical stuff that only occurs on Earth. It has been created by a vast array of organisms working on the soil's parent material — regolith, derived from hard rock — over millions of years.

The result is a matrix of minerals which were not present in the original rocks. Earth's soil is imbued with remarkable physical, chemical and biological characteristics. Meanwhile, the materials on the Moon's surface are basically regolith in its original, untouched form.

One substance goes in, two come out

The Moon's regolith is made up of approximately 45 per cent oxygen. But that oxygen is tightly bound into the minerals mentioned above. In order to break apart those strong bonds, we need to put in energy.

You might be familiar with this if you know about electrolysis. On Earth this process is commonly used in manufacturing, such as to produce aluminium. An electrical current is passed through a liquid form of aluminium oxide (commonly called alumina) via electrodes, to separate the aluminium from the oxygen.

In this case, the oxygen is produced as a by-product. On the Moon, the oxygen would be the main product and the aluminium (or other metal) extracted would be a potentially useful by-product.

It's a pretty straightforward process, but there is a catch: it's very energy hungry. To be sustainable, it would need to be supported by solar energy or other energy sources available on the Moon.

Extracting oxygen from regolith would also require substantial industrial equipment. We'd need to first convert solid metal oxide into liquid form, either by applying heat, or heat combined with solvents or electrolytes. We have the technology to do this on Earth, but moving this apparatus to the Moon — and generating enough energy to run it — will be a mighty challenge.

Earlier this year, Belgium-based start-up Space Applications Services announced it was building three experimental reactors to improve the process of making oxygen via electrolysis. They expect to send the technology to the Moon by 2025 as part of the European Space Agency's in-situ resource utilisation mission.

How much oxygen could the Moon provide?

That said, when we do manage to pull it off, how much oxygen might the Moon actually deliver? Well, quite a lot as it turns out.

If we ignore oxygen tied up in the Moon's deeper hard rock material — and just consider regolith which is easily accessible on the surface — we can come up with some estimates.

Each cubic metre of lunar regolith contains 1.4 tonnes of minerals on average, including about 630 kilograms of oxygen. Nasa says humans need to breathe about 800 grams of oxygen a day to survive. So 630kg oxygen would keep a person alive for about two years (or just over).

Now let's assume the average depth of regolith on the Moon is about 10 metres, and that we can extract all the oxygen from this. That means the top 10 metres of the Moon's surface would provide enough oxygen to support all eight billion people on Earth for somewhere around 100,000 years.

This would also depend on how effectively we managed to extract and use the oxygen. Regardless, the figure is pretty amazing!

Having said that, we do have it pretty good here on Earth. And we should do everything we can to protect the blue planet — and its soil in particular — which continues to support all terrestrial life without us even trying.

The writer is a lecturer in soil science, Southern Cross University, Australia. This article first appeared on www.theconversation.com

PLUS POINTS

Milestone for biology

It is a vital and formative stage of early embryo development, but scientists have long struggled to understand what happens in the weeks after conception and before organs begin to form and mature in the womb.

Now, in what is the first detailed cellular and molecular examination of its kind, described as a "Rosetta stone" moment for modern biology, new light has been shed on the human embryo as it undergoes a process known as gastrulation.

Experts say gastrulation is one of the most critical steps of development, and takes place roughly between days 14 and 21 after fertilisation. During this period, the embryo transforms from a one-dimensional layer of cells and reorganises into a multi-layered and multidimensional structure called the gastrula.

Analysing a single embryo, scientists from the United Kingdom's Oxford University and the Helmholtz Zentrum Munchen, in Germany, identified 11 distinct cell types, including red blood cells and primordial cell germs, which provide the foundations for the later production of egg and sperm cells. The researchers also found that the nervous system had not yet begun to take shape at this stage of development.

Principal study investigator professor Shankar Srinivas, from Oxford University, said, "Our body is made up of hundreds of types of cells. It is at this stage that the foundation is laid for generating the huge variety of cells in our body — it's like an explosion of diversity of cell types."

Scientists say the study, published in *Nature*, is a milestone for developmental biology as ethically acquired human samples at these early stages are exceptionally rare.

The sample was obtained through the Human Developmental Biology Resource, from an anonymous donor who provided consent for researchers to use embryonic material arising from the termination of her pregnancy. It is estimated to be from around 16 to 19 days after fertilisation.

Legally, scientists are only able to grow human embryos in a lab up to the equivalent of 14 days of development — just before the start of gastrulation. Therefore, the knowledge of events beyond 14 days after fertilisation is largely based on studies in animals, such as mice and chickens.

Speaking at a press briefing, Srinivas said, "We didn't see any differentiated neurons to the sample, which tells us that the human embryos at this earlier stage are not equipped to sense their environment in many ways, and certainly can't by any stretch of the imagination be said to be have any mechanism for consciousness for example — the cells just aren't there."

Scientists believe the findings of the study could help to further understand miscarriages and congenital abnormalities, which are thought to be driven by complications that emerge during the gastrulation stage of early development.

"The new study provides a Rosetta Stone for developmental biologists," said Peter Rugg-Gunn, of the Babraham Institute, in Cambridge. "It is already yielding important new insights into how the early cell lineages are formed and positioned in the developing embryo."

— Representational photo/The Independent

Spooky star

In this photograph released by the National Aeronautics and Space Administration-European Space Agency Hubble Space Telescope, CW Leonis glares from deep within a thick shroud of dust. "Lying roughly 400 light years from Earth in the constellation Leo, CW Leonis is a carbon star — a luminous type of red giant star with a carbon-rich atmosphere," said the ESA Hubble's statement.