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THE SCIENCE OF SUMMONING GEOLOGICAL MEMORY

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Continents lay down memories, albeit geological ones, in the form of fossils and other materials that record past events and changes. These 'memories' are often held in sediments that collect in lakes, rivers and shallow seas. Most continents preserve rich memories of their past. But Australia is different. By virtue of its tectonic history and geographic location, it suffers from a great amnesia. Dry, flat and geologically comatose, Australia has relatively few rivers and lakes, its entire freshwater runoff adding up to just one percent of the Mississippi's flow. It has also largely missed out on the geological processes—such as mountain building, glaciation and vulcanism—that help generate the sediments that preserve geological memories.

Sometimes old people whose memories are not the best can surprise us with a vividly recalled event from their childhood. At a few special places, where conditions have been right for accumulating a record of past events, Australia can do a similar thing. The Riversleigh World Heritage site in Queensland is one such place, as is the Willandra Lakes Region World Heritage Area in New South Wales, which preserves exceptional early evidence of the human occupation of Australia. Lake Woods and Girraween Lagoon, which are the subjects of Sonia Leber and David Chesworth's artwork *Where Lakes Once Had Water*, may be less well known but, as the University of Wollongong's Tim Cohen and James Cook University's Cassandra Rowe have demonstrated through their research, both places retain extraordinary geological memories that reveal some of the changes that have shaped Australian wildlife, cultures and landscapes.

Science is just one way of investigating the world, and in *Where Lakes Once Had Water* Leber and Chesworth have created knowing of a different kind. Their exceptional video work witnesses the search for the past as carried out at Lake Woods and Girraween Lagoon. Both are in the Northern Territory but are nevertheless startlingly different. Lake Woods borders the desert, while Girraween Lagoon lies in a much wetter area, in the outer suburbs of Darwin.

As revealed in the opening scenes of *Where Lakes Once Had Water*, delving into the sediments preserved at these places begins with a simple act: a spade is thrust into sand or an auger is pushed through sediments that have accumulated in the lagoon. But much astonishing science follows this initial simple action. Because they are such different places, the two sites require different scientific techniques to unlock their secrets.

And when the appropriate kind of science is applied, it allows us to travel back in time, to a very different Australia—in our imaginations, at least.

Art is a wonderful vehicle for unlocking our imaginations and preparing us for the journey. After all, images are nothing more than pixels or patches of colour—it is our mind that creates meaning from them. The black kite's bird's-eye view of parts of *Where Lakes Once Had Water* transports us into a different world, urging us to soar above our ordinary perceptions of place to take a broader view. But the exceptionally fine granularity of the 4K filming, as well as the double screen, act as clues, directing us to look closely at the minutiae of these grand landscapes. Somehow, *Where Lakes Once Had Water* manages to hold these diametrically opposed concepts simultaneously, and in doing so it opens the work of the researchers to us, revealing a privileged window into the past.

At Lake Woods, the sand revealed by the shovel has been hidden away for tens of thousands of years, ever since wind or water piled it into a low dune by the lake shore. We know this because Earth scientist Tim Cohen subjects the excavated sand to a kind of dating analysis known as optically stimulated luminescence (OSL). OSL dating relies on the fact that each grain of sand is a quartz crystal, and that once buried in sediment they begin accumulating electrons in flaws in the crystal lattice. Sunlight drives the electrons from the crystal lattice, so the grains only start accumulating electrons after they are buried. The electrons that accumulate in the crystal lattice are the result of radioactivity in nearby rocks and sediments releasing energy, so if you know how much radiation is being emitted where the sand grains are buried, you can use OSL dating to determine how long they have been in the ground. In order to obtain an OSL date, researchers expose the sand grains to light in carefully controlled laboratory conditions, and measure the faint emissions produced when the electrons are released from the crystal lattice.

Australia may be poor in water and sediment-creating geological records but it is rich in sand, and the development of OSL dating has revolutionised studies of Australian prehistory. It has allowed for the accurate dating of many events right across the continent that, until the advent of OSL, were long lost in the mists of time. I am a co-author on the paper, published in 2001, that first dated Australia's megafaunal extinction to around forty-six thousand years ago. It was an incredibly exciting project,

and for a few treasured days I was one of only two people on Earth (the other being Richard 'Bert' Roberts of the University of Wollongong) who knew precisely when the great beasts—the diprotodons, giant kangaroos and titanic goannas—had vanished. Holding that secret for the few days before we shared it with a wider circle of colleagues was a magical time for me.

At Girraween Lagoon a different technique known as radiocarbon, or ^{14}C, dating is used. Radiocarbon dating relies on the fact that, in carbon-based life forms, the ratio of two variants of this element (^{14}C and ^{12}C) is constant. But once an organism dies, it stops taking in carbon of any sort, and the ^{14}C, which is unstable, begins to decay. Around half of the ^{14}C taken in by a creature over its lifetime is lost to decay every 5,700 years. So, by measuring the ratio of ^{14}C to ^{12}C, we can determine how long ago a creature, or plant, lived.

Both techniques have their limitations. OSL, for example, is able to date events going back hundreds of thousands but not millions of years, because after a time all of the flaws in the crystal are filled with electrons, meaning that no more can accumulate. And we must remember that when using OSL dating, we are only determining when sand grains were last exposed to sunlight. To determine the age of a bone or artefact buried in the sand requires lots more research. It's not uncommon for objects to be buried, exposed and then reburied in a new context. Radiocarbon dating can only extend back fifty thousand years and, for dates older than around forty thousand years, great care must be taken to ensure that no carbon from elsewhere contaminates the sample. This is because so little ^{14}C is left in these samples that even a tiny amount of contamination can result in a very different, more recent, date. Old carbon, from coal for example, can also contaminate a sample, leading to a false reading that is too old. All of this means that the science of dating requires great precision, and always comes with some level of uncertainty.

The layered sediments preserved in lakes and lagoons can be thought of as a kind of gigantic, environmental tape recorder—in effect, a series of static memories stacked one atop the other to form the equivalent of a soundtrack. Each layer, from the surface one down, is older than the overlying one, and the various layers record the changes in conditions that led to their distinctive colour, thickness and composition. Read the changing conditions in those layers, and we have a geological recording of environmental conditions over time.

The soundtrack of *Where Lakes Once Had Water* is seductive and strange, reflecting this geological tape recording. It is partially derived from the sounds created by the scientists as they go about their work. We hear the machines whirring, clicking and grinding as they labour on our behalf, revealing lost landscapes and environments. It feels to me as if we're listening to a great collective thinking, one in which machines, scientists and artists are creating a vision of a very different Australian prehistory. It's a journey just begun, and many changes of perspective, new discoveries and surprises lie in store.

By dint of a huge amount of careful research, OSL, radiocarbon and other dating techniques have revealed that astounding climatic changes have occurred in Australia over the past hundred thousand years. At different times places like Lake Woods have indeed, as the title *Where Lakes Once Had Water* alludes to, contained water in abundance. Understanding just how and why this occurred has been the work of generations of scientists. And in this era of changing climate it is work of particular importance.

The past is so different from the present that sometimes it's hard to comprehend. Can you imagine an Australia with a very different shape caused by a lowering of the seas, one in which it's possible to walk from New Guinea to Tasmania on dry land? That Australia existed for at least three quarters of the time that humans have lived in Australia. It was only around ten thousand years ago that sea levels began to rise rapidly, creating the Australia that we recognise on the map today.

The lowering of the sea was caused by the accumulation of ice at the poles and, when the ice reached its maximum extent, Australia had a very different climate. Had you been able to see that Ice Age Australia from space, you would have been struck by the great cyclonic swirl of sand dunes that dominated the inland. These dunes were not like the sand dunes of the inland today, which support a variety of vegetation. Instead they were bare, active dunes, like the dunes of Saudi Arabia. And the oculus of the great sand-cyclone lay at Uluru. Back then Australia was a dry, cold land. But paradoxically, many of the inland rivers flowed strongly. That's because there were few trees and grasses to soak up the rain that did fall, and low temperatures reduced evaporation. Imagine swiftly flowing, clear rivers running through vast, sandy dune fields, and you get a sense of the Australia that existed when the sand grains around many Australian lakes last saw the light of day.

Girraween Lagoon offers a very different insight into the vanished landscapes of Australia, for its sediments preserve both charcoal for radiocarbon dating, and pollen. The pollen grains are microscopic, beautiful things with extraordinary detailed surfaces, making some look like imaginary miniature space craft. They can be preserved in abundance in lake sediments, and their unusual shapes and symmetry allow the plants that produced them to be identified to species. Typically, most of the pollen preserved in lake sediments comes from plants that grew locally, around the lake margin. But some kinds of pollen can be blown on the wind for great distances. This makes pollen useful for understanding both the local *and* regional environment.

The evidence provided by fossil pollen can be transformative. When I was still studying for my master's degree in geology at Monash University, I took part in a palaeontological dig at a site in western Victoria. We excavated the bones of a red kangaroo that were around twenty thousand years old. Guided by this find, I imagined that the region, which is today lush volcanic plains grassland, was once a desert. But the palynologist who worked with us was seeing something different. She showed us fossil pollen retrieved from the mud that had come from plants that today only grow hundreds of kilometres to the east, in Australia's alpine country. Later we found seeds of the same alpine plants, so they must have once grown at the site. Seeing the tiny grains on the glass microscope slide altered my imagined past, transporting me not to a desert but to a distant Australia when the lush western district was arid but also cold—a place where red kangaroos could coexist with alpine plants. Today, nothing like this exists in Australia. It is a truly vanished landscape with no analogy in the modern world. The experience acted as a powerful lesson to me that we must look at all the data we have, and be open to the unexpected, as we imaginatively time travel into Australia's deep past. *Where Lakes Once Had Water* provides a powerful stimulus to making that imaginary leap.

Tim Flannery is one of the world's most prominent environmentalists. In 2007 he was named 'Australian of the Year', arguably Australia's highest honour. He delivered the 2002 Australia Day Address to the nation. In 2013 he founded, and is now Chief Councillor of, the Australian Climate Council, Australia's largest and most successful crowd-funded organisation. His latest book is *Europe: A Natural History*, Text Publishing, 2018.


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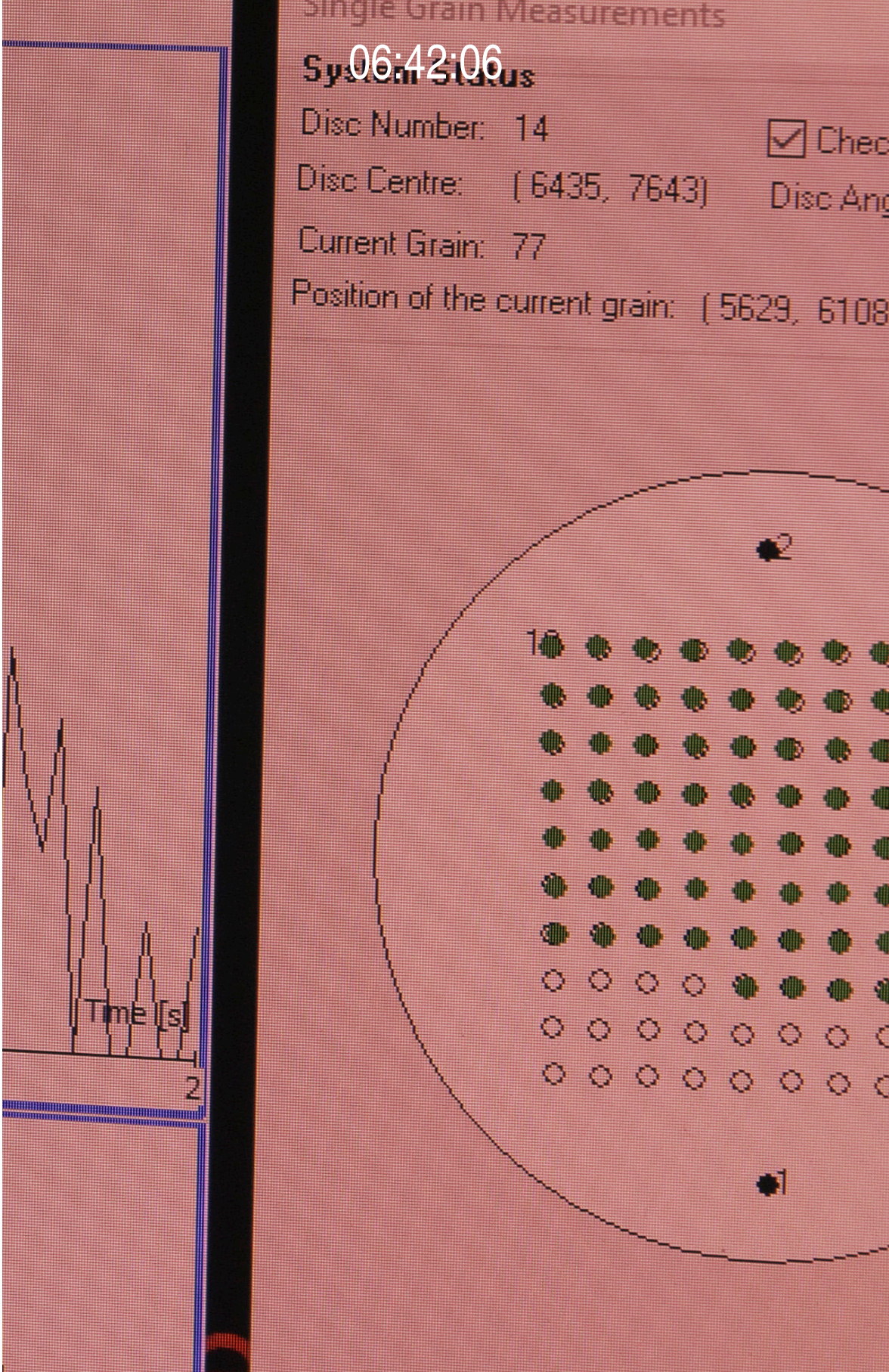
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