New instrument dates old skeleton—'Little Foot' 3.67 million years old

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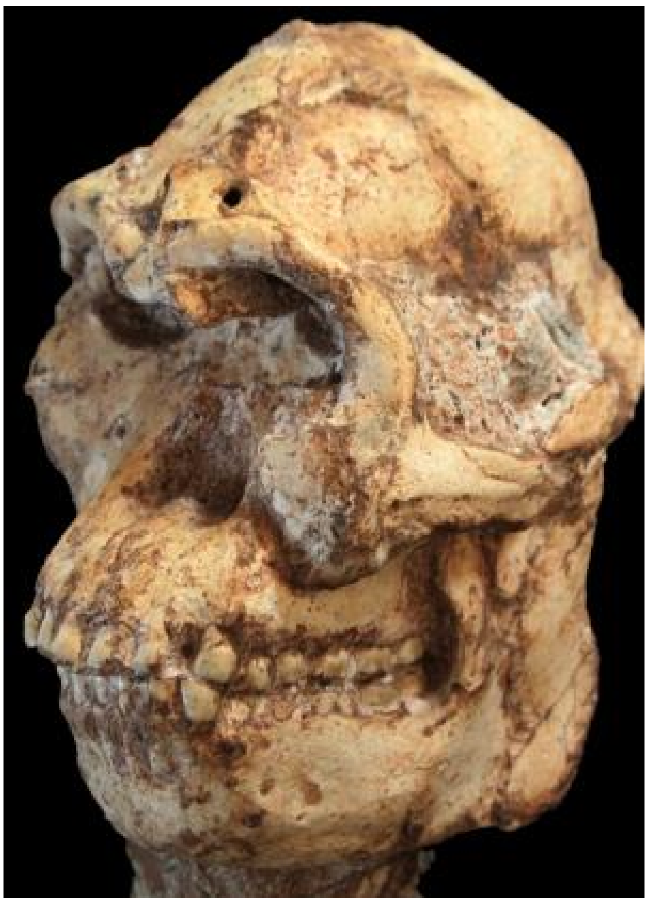


The Little Foot skull (StW 573). Credit: Wits University

A skeleton named Little Foot is among the oldest hominid skeletons ever dated at 3.67 million years old, according to an advanced dating method.

Little Foot is a rare, nearly complete skeleton of *Australopithecus* first discovered 21 years ago in a cave at Sterkfontein, in central South Africa. The new date places Little Foot as an older relative of Lucy, a famous *Australopithecus* skeleton dated at 3.2 million years old that was found in Ethiopia. It is thought that *Australopithecus* is an evolutionary ancestor to humans that lived between 2 million and 4 million years ago.

Stone tools found at a different level of the Sterkfontein cave also were dated at 2.18 million years old, making them among the oldest known stone tools in South Africa.

A team of scientists from Purdue University; the University of the Witwatersrand, in South Africa; the University of New Brunswick, in Canada; and the University of Toulouse, in France, performed the research, which will be featured in the journal *Nature*.

Ronald Clarke, a professor in the Evolutionary Studies Institute at the University of the Witwatersrand who discovered the Little Foot skeleton, said the fossil represents *Australopithecus prometheus*, a species very different from its contemporary, *Australopithecus afarensis*, and with more similarities to the *Paranthropus* lineage.

"It demonstrates that the later hominids, for example, *Australopithecus africanus* and *Paranthropus* did not all have to have derived from *Australopithecus afarensis*," he said. "We have only a small number of sites and we tend to base our evolutionary scenarios on the few fossils we have from those sites. This new date is a reminder that there could well have been many species of *Australopithecus* extending over a much wider area of Africa."

There had not been a consensus on the age of the Little Foot skeleton, named for four small foot bones found in a box of animal fossils that led to the skeleton's discovery. Previous dates ranged from 2 million to 4 million years old, with an estimate of 3 million years old preferred by paleontologists familiar with the site, said Darryl Granger, a professor of earth, atmospheric and planetary sciences at Purdue, who in collaboration with Ryan Gibbon, a former postdoctoral researcher, led the team and performed the dating.

The dating relied on a radioisotopic dating technique pioneered by Granger coupled with a powerful detector originally intended to analyze solar wind samples from NASA's Genesis mission. The result was a a relatively small margin of error of 160,000 years for Little Foot and 210,000 years for the stone tools.

The technique, called isochron burial dating, uses radioisotopes within several rock samples surrounding a fossil to date when the rocks and the fossil were first buried underground.

The burial dating relies on measuring radioactive isotopes aluminum-26 and beryllium-10 in quartz within the rock. These isotopes are only created when the rock is exposed to cosmic rays. When a rock is on the surface, it builds up these isotopes. When it is buried or deposited in a cave, the isotopes decay at known rates. The ratio of the remaining aluminum-26 and beryllium-10 can be used to determine how long the rock has been underground, Granger said.

A graph of the isotope ratios, called an isochron, is created for the rock samples. If a strong isochron line forms, it increases the confidence that the samples on the line meet the criteria to be good candidates for accurate dating. Samples that have been compromised, due to reburial or natural movement of sediment within a site, fall above or below the line can be tossed out of the analysis, Granger said.

"If we had only one sample and that rock happened to have been buried, then re-exposed and buried again, the date would be off because the amount of radioisotopes would have increased during its second exposure," he said. "With this method we can tell if that has happened or if the sample has remained undisturbed since burial with the fossil. It is expensive and a lot of work to take and run multiple samples, but I think this is the future of burial dating because of the confidence one can have in the results."

Artifacts from the Oldowan are shown. Credit: Wits University

Out of 11 samples collected from the site over the past decade, nine fell into a single isochron line, which is a very robust result, he said.

This was Granger's second attempt at dating the fossil through the burial dating technique and a chance to prove its abilities. In 2003 he estimated the fossil to be around 4 million years old, give or take a few hundred thousand years. The dates were questioned because this earlier work could not show whether the burial dates were compromised by earlier burial elsewhere in the cave, he said.

"The original date we published was considered to be too old, and it wasn't well received," Granger said. "However, dating the Little Foot fossil as 3.67 million years old actually falls within the margin of error we had for our original work. It turns out it was a good idea after all."

Granger's original attempt was the first time aluminum-26 and beryllium-10 radioisotopic dating had been used to determine the age of a fossil. He developed the method in 1997 and first used it to study changes in mountains, rivers and other geological formations. Because of their very slow rate of decay, these particular radioisotopes allow dating to reach back millions of years, much further in history than the more commonly known carbon-14 dating that can only stretch back about 50,000 years, he said.

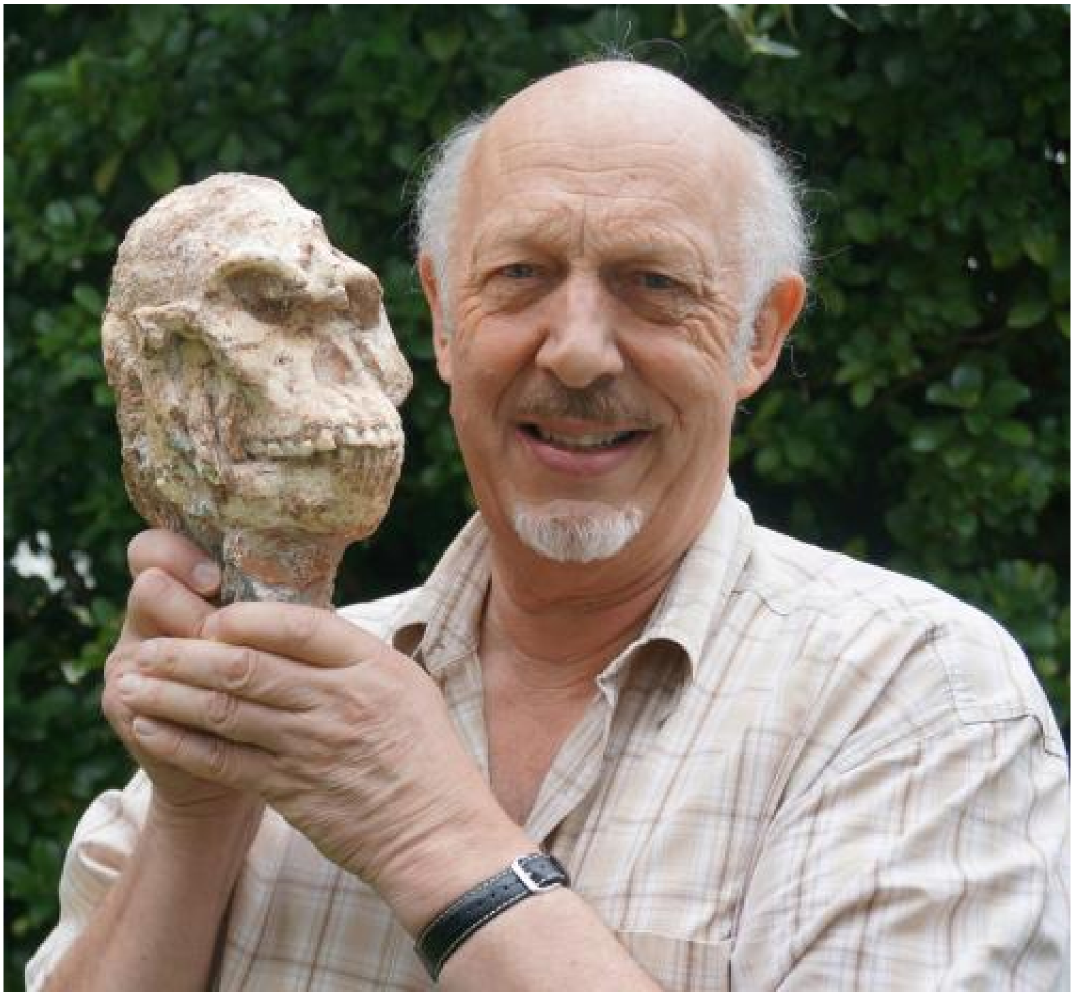
Only a small amount of the radioisotopes remain in the quartz after millions of years, and it can only be measured by the ultrasensitive analysis of accelerator mass spectrometry. Purdue's Rare Isotope Measurement Laboratory, or PRIME Lab, is one of only two laboratories in the nation with equipment capable of performing this kind of dating, said Marc Caffee, a Purdue professor of physics and director of the PRIME Lab who was involved in the research.

Gibbon joined Granger in his work on the Sterkfontein samples in 2010 and was a key player in the research. Granger and Gibbon decided to use the new isochron technique to test whether the quartz was reworked and if the dates could be trusted.

To measure the radioisotopes the quartz is separated from the rocks and then pulverized and dissolved into a solution that can be analyzed by the accelerator and detector. A common difficulty in measuring the presence of trace amounts of specific radioisotopes is the presence of other radioisotopes. In past measurement attempts of the Sterkfontein samples using a different detector, aluminum-26 was especially difficult to measure because of magnesium-26.

"We had given up and nearly walked away from the project thinking we had failed," he said. "Then the new detector was completed, and we thought we would give it one last try."

This time the team used the PRIME Lab's powerful accelerator mass spectrometer and a new detector, called a gas-filled magnet detector, to measure the radioisotopes.



Professor Ron Clarke from Wits University is shown with Little Foot. Credit: Wits University

"We succeeded in our measurement, but we were surprised the dates were so old," Granger said. "We double-and triple-checked our results, running the measurement again and again."

The gas-filled magnet creates a different charge on the two radioisotopes and throws the magnesium-26 on a different path with a curvature that misses the detector. This lowers the magnesium ratio and increases the aluminum-26 count in the sample that makes it to the detector, which results in a much smaller margin of error in the measurement, Caffee said.

The gas-filled magnet detector was originally to be used to analyze samples of solar wind collected by the Genesis spacecraft. Unfortunately, the space capsule carrying the samples crashed in 2004 on its return to Earth. The crash delayed analysis of the Genesis samples, but Caffee continued to build the detector and it was completed the summer of 2014. Caffee has since used it to perform analysis for other projects, including those from the Sterkfontein site.

"Only a few detectors of this kind exist in the world," Caffee said. "One of the reasons I came to Purdue was to be a part of the revolutionary science that can be done when such resources are applied to challenging problems. These results highlight what can be accomplished through a collaboration that spans multiple disciplines. It couldn't have happened without the unique skills and resources each person brought to the table."

In addition to Granger, Clarke, Gibbon and Caffee, co-authors of the paper include Kathleen Kuman, a professor in earlier and middle stone age archaeology in the School of Geography, Archaeology and Environmentla Studies at the University of the Witwatersrand in Johannesburg, South Africa; and Laurent Bruxelles, a researcher in geomorphology and karstology at the French National Institute for Preventive Archaeological Research in Nimes, France.

The tools from the site had earlier been determined to be Oldowan, a simple flaked stone tool technology considered the earliest stone tool industry in prehistory.

The new Sterkfontein date for the Oldowan artifacts shows that this industry is consistently present in South Africa by 2 million years ago, a much earlier age for tool-bearing hominids than previously anticipated in this part of Africa, Kuman said.

"It is now clear that the small number of Oldowan sites in southern Africa is due only to limited research and not to the absence of these hominids," she said.

Granger looks forward to applying the technique to more fossils at Sterkfontein and elsewhere.

More information: Darryl E. Granger et al, New cosmogenic burial ages for Sterkfontein Member 2 Australopithecus and Member 5 Oldowan, *Nature* (2015). DOI: 10.1038/nature14268 , www.nature.com/articles/nature14268

Provided by Purdue University

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