

New technology interprets archaeological findings from Biblical times

January 4 2024



Credit: Tel-Aviv University

A breakthrough achieved by researchers from four Israeli universities—Tel Aviv University, The Hebrew University of Jerusalem, Bar-Ilan University and Ariel University—will enable archaeologists to identify burnt materials discovered in excavations and estimate their firing temperatures.

Applying their method to findings from ancient Gath (Tell es-Safi in central Israel), the researchers validated the Biblical account, "About this time Hazael King of Aram went up and attacked Gath and captured it. Then he turned to attack Jerusalem" (2 Kings 12, 18). They explain that, unlike previous methods, the new technique can determine whether a certain item (such as a mud brick) underwent a firing event even at relatively low temperatures, from 200°C and up. This information can be crucial for correctly interpreting the findings.

The multidisciplinary study was led by Dr. Yoav Vaknin from the Sonia & Marco Nadler Institute of Archaeology, Entin Faculty of Humanities, at Tel Aviv University, and the Palaeomagnetic Laboratory at The Hebrew University. The paper has been [published](#) in *PLOS ONE*.

Prof. Lipschits said, "Throughout the Bronze and Iron Ages the main building material in most parts of the Land of Israel was mud bricks. This cheap and readily available material was used to build walls in most buildings, sometimes on top of stone foundations. That's why it's so important to understand the technology used in making these bricks."

Dr. Vaknin added, "During the same era dwellers of other lands, such as Mesopotamia where stone was hard to come by, would fire mud bricks in kilns to increase their strength and durability. This technique is mentioned in the story of the Tower of Babel in the Book of Genesis: 'They said one to another, Come, let us make bricks and fire them thoroughly. So they used brick for stone' (Genesis 11, 3)."

"Most researchers, however, believe that this technology did not reach the Land of Israel until much later, with the Roman conquest. Until that time the inhabitants used sun-dried mud bricks. Thus, when bricks are found in an archaeological excavation, several questions must be asked: First, have the bricks been fired, and if so, were they fired in a kiln prior to construction or in situ, in a destructive conflagration event? Our

method can provide conclusive answers."

The new method relies on measuring the [magnetic field](#) recorded and "locked" in the brick as it burned and cooled down.

Dr. Vaknin said, "The clay from which the bricks were made contains millions of ferromagnetic particles—minerals with [magnetic properties](#) that behave like so many tiny 'compasses' or magnets. In a sun-dried mud brick the orientation of these magnets is almost random, so that they cancel out one another."

"Therefore, the overall magnetic signal of the brick is weak and not uniform. Heating to 200°C or more, as happens in a fire, releases the magnetic signals of these magnetic particles and, statistically, they tend to align with the earth's magnetic field at that specific time and place. When the brick cools down, these magnetic signals remain locked in their new position and the brick attains a strong and uniformly oriented magnetic field, which can be measured with a magnetometer. This is a clear indication that the brick has, in fact, been fired."

In the second stage of the procedure, the researchers gradually "erase" the brick's magnetic field, using a process called thermal demagnetization. This involves heating the brick in a special oven in a palaeomagnetic laboratory that neutralizes the earth's magnetic field.

The heat releases the magnetic signals, which once again arrange themselves randomly, canceling each other out, and the total magnetic signal becomes weak and loses its orientation.

Dr. Vaknin said, "We conduct the process gradually. At first, we heat the sample to a [temperature](#) of 100°C, which releases the signals of only a small percentage of the magnetic minerals. We then cool it down and measure the remaining magnetic signal. We then repeat the procedure at

temperatures of 150°C, 200°C, and so on, proceeding in small steps, up to 700°C."

"In this way the brick's magnetic field is gradually erased. The temperature at which the signal of each mineral is 'unlocked' is approximately the same as the temperature at which it was initially 'locked,' and ultimately, the temperature at which the magnetic field is fully erased was reached during the original fire."

The researchers tested the technique in the laboratory: they fired mud bricks under controlled conditions of temperature and magnetic field, measured each brick's acquired magnetic field, then gradually erased it. They found that the bricks were completely demagnetized at the temperature at which they had been burned—proving that the method works.

Dr. Vaknin said, "Our approach enables identifying burning which occurred at much lower temperatures than any other method. Most techniques used for identifying burnt bricks are based on actual changes in the minerals, which usually occur at temperatures higher than 500°C—when some minerals are converted into others."

Dr. Eliyahu Behar added, "One of the common methods for identifying mineralogical changes in clay (the main component of mud bricks) due to exposure to high temperatures is based on changes in the absorption of infrared radiation by the various minerals. In this study we used this method as an additional tool to verify the results of the magnetic method."

Dr. Vaknin added, "Our method is much more sensitive than others because it targets changes in the intensity and orientation of the magnetic signal, which occur at much lower temperatures. We can begin to detect changes in the magnetic signal at temperatures as low as 100°C, and

from 200°C and up the findings are conclusive."

In addition, the method can determine the orientation in which the bricks cooled down. Dr. Vaknin said, "When a brick is fired in a kiln before construction, it records the direction of the earth's magnetic field at that specific time and place. In Israel this means north and downward. But when builders take bricks from a kiln and build a wall, they lay them in random orientations, thus randomizing the recorded signals."

"On the other hand, when a wall is burned in-situ, as might happen when it is destroyed by an enemy, the magnetic fields of all bricks are locked in the same orientation."

After proving the method's validity, the researchers applied it to a specific archaeological dispute: was a specific brick structure discovered at Tell es-Safi—identified as the Philistine city of Gath, home of Goliath—built of pre-fired bricks or burned on location? The prevalent hypothesis, based on the Old Testament, historical sources, and Carbon-14 dating attributes the destruction of the structure to the devastation of Gath by Hazael, King of Aram Damascus, around 830 BCE.

However, a previous paper by researchers including Prof. Maeir, head of the Tell es-Safi excavations, proposed that the building had not burned down, but rather collapsed over decades, and that the fired bricks found in the structure had been fired in a kiln prior to construction. If this hypothesis were correct, this would be the earliest instance of brick-firing technology discovered in the Land of Israel.

To settle the dispute, the current research team applied the new method to samples from the wall at Tell es-Safi and the collapsed debris found beside it.

The findings were conclusive: the magnetic fields of all bricks and collapsed debris displayed the same orientation—north and downwards. Dr. Vaknin said, "Our findings signify that the bricks burned and cooled down in-situ, right where they were found, namely in a conflagration in the structure itself, which collapsed within a few hours. Had the bricks been fired in a kiln and then laid in the wall, their magnetic orientations would have been random."

"Moreover, had the structure collapsed over time, not in a single fire event, the collapsed debris would have displayed random magnetic orientations. We believe that the main reason for our colleagues' mistaken interpretation was their inability to identify burning at temperatures below 500°C. Since heat rises, materials at the bottom of the building burned at relatively low temperatures, below 400°C, and consequently, the former study did not identify them as burnt—leading to the conclusion that the building had not been destroyed by fire."

"At the same time, bricks in upper parts of the wall, where temperatures were much higher, underwent mineralogical changes and were therefore identified as burnt—leading the researchers to conclude that they had been fired in a kiln prior to construction. Our method allowed us to determine that all bricks in both the wall and debris had burned during the conflagration: those at the bottom burned at relatively low temperatures, and those that were found in higher layers or had fallen from the top—at temperatures higher than 600°C."

Prof. Maeir said, "Our findings are very important for deciphering the intensity of the fire and scope of destruction at Gath, the largest and most powerful city in the Land of Israel at the time, as well as understanding the building methods prevailing in that era. It's important to review conclusions from previous studies, and sometimes even refute former interpretations, even if they came from your own school."

Prof. Ben-Yosef added, "Beyond their historical and archaeological significance, ancient building methods also had substantial ecological implications. The brick firing technology requires vast quantities of combustive materials, and in ancient times this might have led to vast deforestation and even loss of tree species in the area."

"For example, certain species of trees and shrubs exploited by the ancient copper industry in the Timna Valley have not recovered to this day and the industry itself ultimately collapsed once it had used up its natural fuels. Our findings indicate that the brick firing technology was probably not practiced in the Land of Israel in the times of the Kings of Judah and Israel."

Other contributors include Prof. Ron Shaar from the Institute of Earth Sciences at The Hebrew University, Prof. Erez Ben-Yosef and Prof. Oded Lipschits from the Sonia & Marco Nadler Institute of Archaeology at Tel Aviv University, Prof. Aren Maeir from the Martin (Szusz) Department of Land of Israel Studies and Archaeology at Bar-Ilan University and Dr. Adi Eliyahu Behar from the Department of Land of Israel Studies and Archaeology and the Department of Chemical Sciences at Ariel University.

More information: Yoav Vaknin et al, Applying thermal demagnetization to archaeological materials: A tool for detecting burnt clay and estimating its firing temperature, *PLOS ONE* (2023). [DOI: 10.1371/journal.pone.0289424](https://doi.org/10.1371/journal.pone.0289424)

Provided by Tel-Aviv University

Citation: New technology interprets archaeological findings from Biblical times (2024, January 4) retrieved 29 April 2024 from

<https://phys.org/news/2024-01-technology-archaeological-biblical.html>

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