



# Mystery of the Pyramids Solved

One of the great mysteries of the pyramids may have been solved—by state-of-the-art radar systems that can penetrate the desert sand.

The Egyptian pharaohs built 90 pyramids, with the most famous, at Giza, constructed almost 5,000 years ago. At nearly 500 feet, the Great Pyramid of Khufu was the world's tallest manmade structure for almost 4,000 years!

To build it, 20,000 workers assembled 2.3 million stone blocks, each weighing tons.

Scientists have long wondered how ancient people, without modern energy, wheels, pulleys or even iron tools, could have cut and moved such massive stones from the quarries in eastern Egypt to the pyramid sites.

It was long thought they were transported by boat along the Nile—but many pyramids are miles from the river.

From today's river that is.

Recently, satellite and ground penetrating radar identified an ancient tributary of the Nile that ran next to many of the pyramid complexes.

The advanced radar even revealed what may have been ports, to deliver the stone blocks and huge labor force.

These channels filled with desert sand when the region dried out millennia ago, and centuries of agriculture obscured the geologic signs of the tributary.

This finding also suggests there may be entire settlements along the ancient waterway that were entombed by the desert—just waiting to be discovered.

Pyramids of the Giza Necropolis lie 5.6 miles (9 kilometers) west of the current course of the Nile River and include Egypt's two largest pyramids, the Great Pyramid of Khufu (in the distance) and the Pyramid of Khafre (with the limestone cladding), as well as the Pyramid of Menkaure (foreground) and the Great Sphinx (not shown). All were built during the Fourth Dynasty of the Old Kingdom of ancient Egypt, between 2613 and 2494 BC. The site also includes several temples, cemeteries, and the remains of a workers' village.

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# Background: Mystery of the Pyramids Solved

**Synopsis:** The Egyptian pyramids are wonders of human innovation, constructed from 4,700 to 3,500 years ago. While many depictions of Egyptian culture were carved in stone, their builders didn't leave many records of how these structures were constructed from enormous stones. Researchers have recently used radar remote sensing to locate vestiges of an abandoned Nile River branch that may have been instrumental in moving both building materials and workers.

- Over more than 1,000 years, 90 pyramids were built in ancient Egypt to demonstrate the status, and securely house the bodies, of deceased royalty, providing a place where offerings could be brought.
  - During more than four centuries of the First and Second Dynasties, Egyptians buried their pharaohs in rectangular mudbrick burial structures called mastabas. Tomb robbers found these were easy to plunder through their tops.
  - To better protect the deceased, the first step toward pyramid construction occurred during the Third Dynasty (2687–2613 BC). Around 2650 BC (4,675 years ago) the Step Pyramid, was built for the first pharaoh of the Third Dynasty, Djoser, by his vizier (high-level official), Imhotep. It was essentially five progressively smaller structures stacked on top of a preexisting mastaba creating its unique stepped appearance. It was clad in durable white Tura Limestone to deter grave robbers. Below it was a maze of long corridors and a 90 ft (28 m) vertical shaft leading to the burial chamber.
- During the Fourth Dynasty (2613–2494 BC), its first ruler, Sneferu, was responsible for an evolution in pyramid construction that resulted in their characteristic pointed shapes.
  - Sneferu built the Bent Pyramid, with the angle of its sides changing from 54° to 43°, possibly to manage stability. Sneferu's final pyramid, the Red Pyramid used the same 43° slope and simplified many other previous pyramid design features. The Bent Pyramid is unique because much of its original outer casing of polished white Tura Limestone is still intact.



The northwest corner of Mastaba al-Fir'aun in Saqqara, Egypt.

Credit: Jon Bodsworth, copyrighted free use, via Wikimedia Commons



The Step Pyramid of Djoser at Saqqara, Egypt was finished around 2650 B.C.

Credit: Francisco Anzola, CC BY 2.0, via Wikimedia Commons

## References: Mystery of the Pyramids Solved

- The Pyramids Were Built along an Abandoned Nile Branch | Nature
- Majority of Pyramids Built along Long-Lost Branch of Nile | Sci News
- How Old Are the Egyptian Pyramids? | LiveScience
- How Pyramids Were Built Inspires Engineering Historians | Northrop Grumman
- How Have the Egyptian Pyramids Lasted So Long? | BBC Science Focus



Contributors: Juli Hennings, Harry Lynch

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- Khufu succeeded his father Sneferu as the second pharaoh, commissioning the Great Pyramid at Giza around 2570 BC

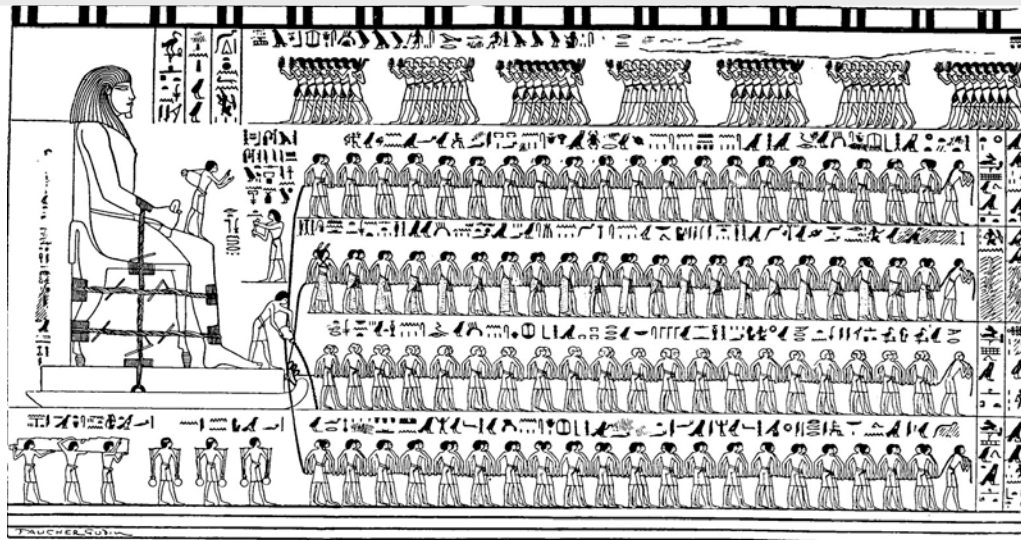


The Bent Pyramid is located at the royal necropolis of Dahshur, 25 miles (40 kilometers) south of Cairo. Transitional from stepped to smooth sided pyramids, its lower part rises at  $54^\circ$  while its top was built at  $43^\circ$  around 2600 BC. Note the intact cladding of smooth Tura Limestone.

Credit: Jorge Láscar from Melbourne, Australia, CC BY 2.0, via Wikimedia Commons

(4,595 years ago), one of the Seven Wonders of the Ancient World. With  $52^\circ$  sides, it is 481 ft (147 m) tall and was the world's tallest human-made structure for 3,881 years, finally succeeded in 1311 by the Lincoln Cathedral in Lincoln, England. The Great Pyramid was also covered in white Tura Limestone.

- Khufu's son Khafre built an additional slightly smaller pyramid and the Sphinx of Giza during his reign from 2558–2532 BC. The Pyramid of Khafre still retains some of the cladding of white Tura Limestone.
- The last pyramid was built for Ahmose I of the Eighteenth Dynasty around 1550 BC (3,575 years ago) in Abydos, Egypt, after which Egyptian royalty was buried in the Valley of the Kings (near Thebes/Luxor) until about 1075 BC.
- For millennia scientists have tried to solve the mystery of how the Egyptians managed to build these huge structures, some of which have endured for nearly 4,700 years. (For reference, Stonehenge was built from 5,100 to 3,600 years ago, between 3100 and 1600 BC.)



This ancient Egyptian wall painting from a Twelfth Dynasty tomb shows a huge statue being hauled across the sand on a sledge in about 1800 BC. Note the worker who appears to be pouring water onto the sand in front of the sledge while others appear to be carrying water to replenish his supply. Recent studies have shown that the coefficient of friction is halved in sand with a water content of 5%, halving the workforce required to pull a sledge.

Credit: Internet Archive Book Images, public domain, via Wikimedia Commons

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- Herodotus, the Greek historian (484–420 BC), deduced that the Great Pyramid took about 20 years to build. He calculated that it would have taken a workforce of as many as 100,000 men, some who joined the effort from the agricultural workforce when they couldn't work in the fields because of Nile flooding.
- Recent excavations suggest a permanent workforce for this pyramid may have totaled around 20,000 workers, along with those who supported them like priests, physicians and food preparers such as bakers. They are not thought to have been slaves.
- At the pyramid sites, it is most likely that they constructed one or more ramps that spiraled around the pyramid as it rose, and that these ramps were used to haul blocks of stone up the structure using sled-like sledges, rollers and levers.
- Many studies have focused on plausible methods of moving the huge stone blocks around the construction site.
- But how were large stones, such as the brilliant white Tura Limestone facing stones, transported miles from quarries east of the Nile to the pyramid construction sites on the edge of Egypt's inhospitable Western Desert?
  - Starting with the Saqqara Step Pyramid 4,675 years ago, the Tura Limestone was used for cladding on these structures, both to protect them from grave robbers and weather, and to make them stand out as beacons in the desert.
  - Most of the 2.3 million blocks of the Great Pyramid weigh 1 to 2.5 tons each, and many of the interior blocks were quarried nearby on the Giza Plateau.
  - East of the Nile, miners tunneled deep underground to cut large blocks of the dense, featureless, fine-grained Tura Limestone that was deposited about 42 million years ago during the Lutetian Stage of the Eocene Epoch.



These original Tura Limestone facing stones remain at the base of the north face of the Great Pyramid. They were formed into trapezoidal shapes to give the pyramid its smooth exterior.

Credit: Jon Bodsworth, copyrighted free use, via Wikimedia Commons

- Ancient Egyptians did not have pulleys, wheels, or iron tools, so they had to rely on copper chisels, drills and saws as well as harder varieties of rock to shape the limestone blocks.
- The workers used levers, rollers and sledges to move these special stones to harbors along the east bank of the Nile, then they were transported by boat.
- On arrival at their destination harbors on the west bank, the blocks were placed on sledges which were pushed or pulled to their delivery locations.
- They also transported other types of exotic stones along the Nile. The largest granite stone in the "King's Chamber" of the Great Pyramid weighs around 80 tons and was quarried 500 mi (800 km) upstream at Aswan.
- Today the Nile runs along the eastern side of its fertile 3 to 5 mi wide (5–8 km) floodplain, the remainder of which is filled with agricultural fields.

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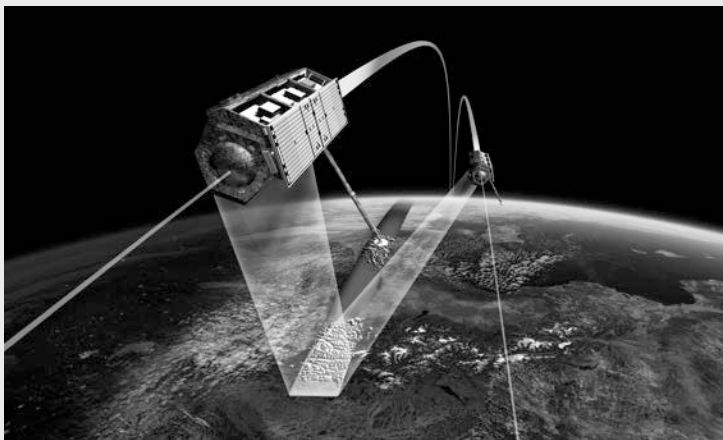
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The radar satellite TanDEM-X flies in close formation with its 'twin' TerraSAR-X. This image shows the two satellites flying together—"side-by-side"—1,150 feet (350 meters) apart. The two satellites operate in synchronization and are able to produce 3D results.

Credit: DLR, CC BY 3.0, via Wikimedia Commons

- Pyramid complexes are located along the foothills of the Western Desert Plateau around 3 to 5 mi (5–8 km) west of the current Nile River course from Lisht to Giza.
- Researchers wondered why their builders would place pyramid construction sites so far from a viable watercourse, increasing the distance they would need to move the bulky stones over land.
- Now, a new radar study has identified an ancient, buried branch of the Nile on the western side of the valley that is at least 40 mi (64 km) long, adjacent to many of the pyramid complexes.
  - The modern agricultural activity in the valley made it impossible to see any ancient landscape detail using optical remote sensing, but this new study used remote sensing from synthetic aperture radar (SAR) satellite (TanDEM-X) to penetrate the ground surface, discovering the first evidence of a former western Nile tributary they named the Ahramat Branch.



Ground penetrating radar (GPR) collection. The wheel trailing behind the transmitter-receiver antennas is an odometer that controls data collection.

Credit: Archaeo-Physics LLC, public domain, via Wikimedia Commons

- They followed up using ground penetrating radar (GPR) and drilled two core holes to confirm the existence of the ancient riverbed which lies 1.5 to 6.5 mi (2.5–10.25 km) west of today's Nile with a channel width and depth rivaling today's Nile.
- Using a variety of tools, they were able to directly document some segments while inferring connecting segments where data was sparse.
  - They have also identified causeways that run perpendicular from the old river branch toward the pyramid construction sites that probably served as harbors, aiding delivery of both building materials and workers.
  - Nile delta sediment loads suggest the flow of the river was greater in the past, so it is plausible that this waterway would have served as a transportation artery.
  - A few centuries later, drought plagued the region, with Sahara sand blown from the Western Desert silting up the western branch and causing the river flow to migrate east. It is possible that buried archaeological sites including ancient settlements and temples await discovery along the ancient channel.

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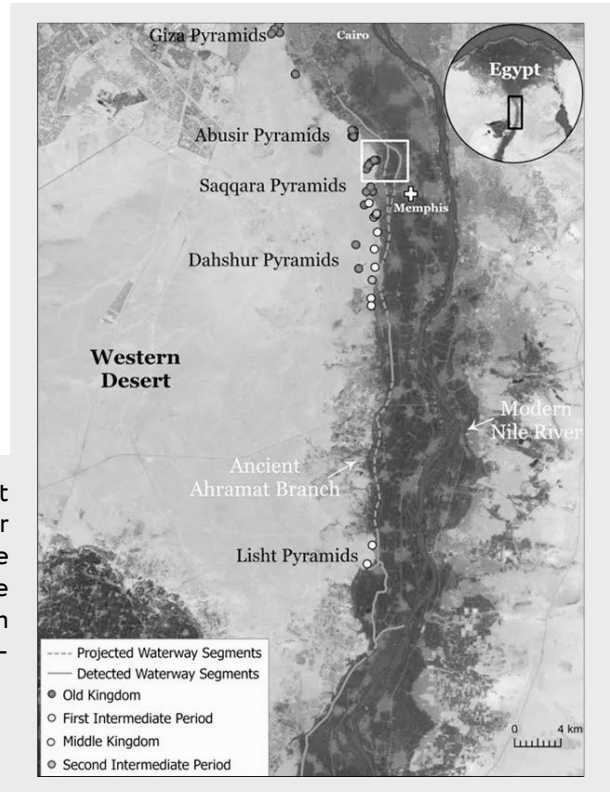
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The watercourse of the ancient Ahramat Branch runs adjacent to a large number of pyramids complexes dating from the Old Kingdom to the Second Intermediate Period, spanning nearly a millennium from the Third to Thirteenth Dynasties (2686–1649 BC).

Credit: Ghoneim et al. (2024), CC BY 4.0, via Springer Nature



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