



Scanning by Eye and Experience: In Search of the Human Hand That Built the Great Pyramid

by Mark Lehner

The Great Pyramid of Giza, more than 4,500 years old, remains a never ending source of fascination. For years people have scrutinized it, theorized about construction methods, and speculated about hidden chambers. Recently ScanPyramids¹ announced that they found “anomalies,” possible interior spaces when they used muon tomography and infrared thermography to scan the pyramid.

We at AERA are also trying to understand how the Great Pyramid was built, but not with high-tech methods to probe its interior. We map the builders’ marks in the surface around the base of the pyramid.

The builders constructed the massive tomb on the limestone bedrock of the Moqattam Formation. So they started with a very solid, but sloping surface. They quarried away the rough bedrock to level it for a courtyard around the pyramid perimeter.

To help them maneuver and lay massive stone blocks they cut and chiseled post holes, lever sockets, lines, and other traces in addition to their levelling cuts. These marks are not attention-grabbers. When people visit the Great Pyramid they look up, not down at the plethora of holes, cuts, and lines on the floor around the monument. Even Egyptologists for the most part have shown little interest in these markings on the bedrock. But, the overall set of “tracks” reveal much about the builders’ movements and *modus operandi*. They offer insights into the building process.

The marks were never meant to be seen. The builders laid a thick limestone pavement over the bedrock floor of the

Mark Lehner draws the socket at the northwest corner of the pyramid during the 2016 Glen Dash Foundation Survey. Though the sockets have been much discussed, no one has ever drawn and published their form in detail. The survey team mapped the feature, but Mark’s drawings will include a lot of detail the photos and the total station will not pick up. It’s the human hand and eye at work. Photo by Ashraf Abd el-Aziz.

court that surrounded the pyramid, enclosed by a 10-foot tall enclosure wall set 33.5 feet (10.2 meters) out from the pyramid platform. When robbers stripped the pyramid of its outer casing, they removed most of the enclosure wall and the pavement, except for big patches on the north and west. The exposed bedrock foundation shows the bedrock cuttings of Khufu’s builders—their backstage operations.

What Can the Holes Tell Us?

I have been photographing and thinking about all these features since the early 1980s. In 1983, I published an article about a series of large holes that runs parallel to the pyramid platform. But I could only provide a schematic map of the holes.

Now, 33 years later, Glen Dash has helped make it possible to thoroughly map all the holes and other features for the first time.

During the past two seasons, as part of the Glen Dash Foundation Survey (GDFS), an AERA team tracked these “footprints” of the pyramid builders. Amr Zakaria, who learned to survey in the AERA-ARCE Field Schools, took coordinates on features with the total station, while Ashraf Abd el-Aziz labeled and photographed every one of them. All of the data went

into a database. At the end of the 2016 survey, Amr plotted all the features in AutoCAD. AERA GIS Director Rebekah Miracle imported the data into our GIS and generated maps, such as the one below, which shows the 2,898 features we recorded: 1,000 holes in the bedrock floor and 1,898 quarry features.

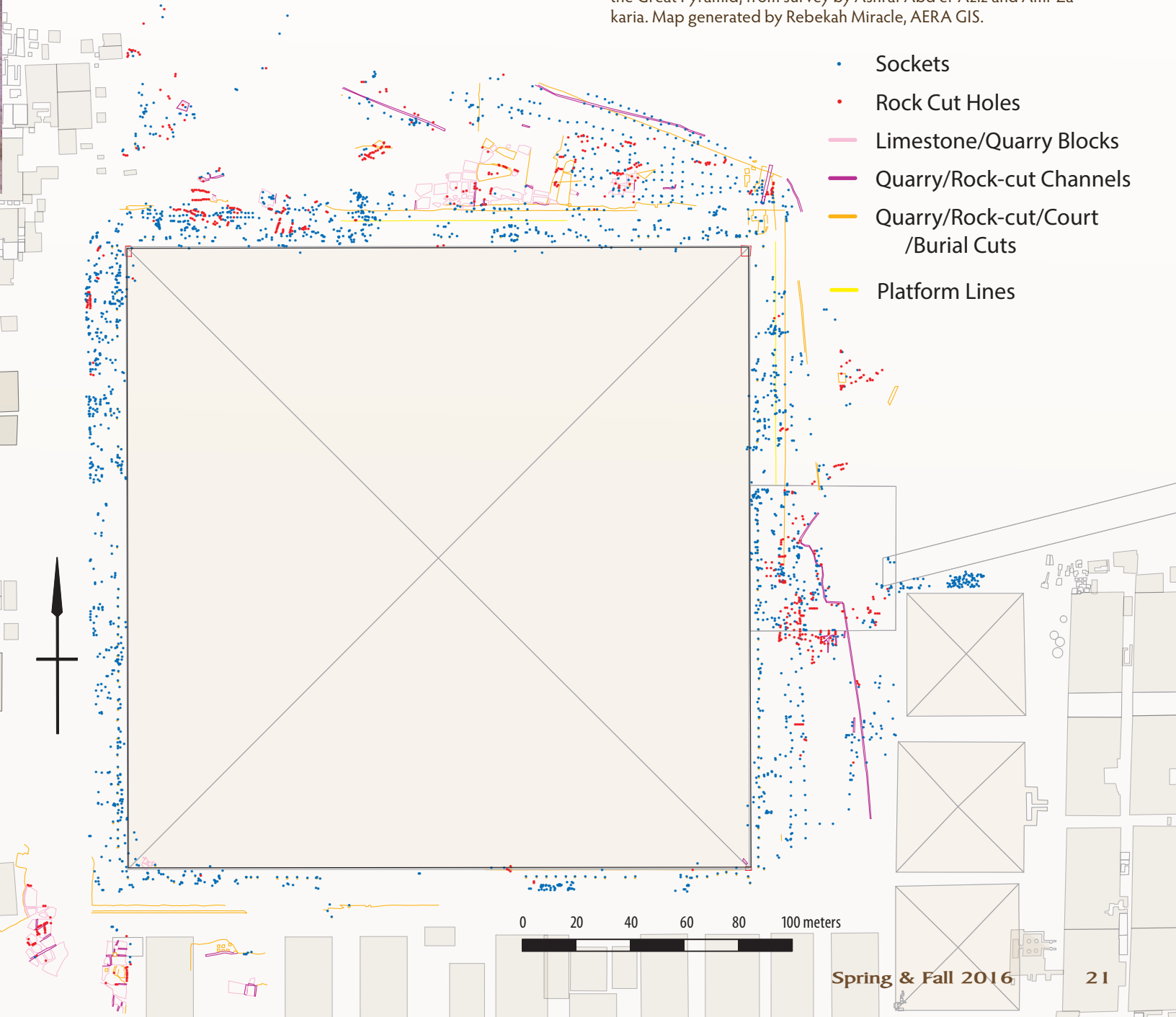
Now, we can work with this data to try to understand what these marks might tell us about how the builders and engineers went about creating the Great Pyramid. We can zoom in on any feature, or group of features, to gain insight into the techniques and operations of the ancient surveyors. For example, some of the holes track their use of offsets and reference lines for setting and trimming the pyramid platform (described below).

Lever Sockets

All around the pyramid court we see wedge-shaped cuttings, deeper at one end, and slightly wider than a wooden railroad

tie, in sets of three or four in a row (photo at left). Workers cut these as sockets to wedge the ends of their wooden levers under large, heavy stones that had ended up flat on the bedrock floor. Having worked at Giza with masons and quarrymen as they moved heavy stones, I know you generally do not want to let a block rest flat on one side until it reaches its final destination. It is hard to get a lever under a large block lying on one flat side—to “get purchase” as they say—in order to lift and shimmy it about. When workers move big, heavy stones by tumbling (which they often do), they tip them onto a smaller rock, such as a hard round chert cobble stone or small pile of limestone chips. Positioned on these ball bearing-like objects, the stone can easily be tipped and tumbled again, or turned on its hard pivot by only one or two workers. When the 4th

Plot of the holes and other features cut into the bedrock floor around the Great Pyramid, from survey by Ashraf Abd el-Aziz and Amr Zakaria. Map generated by Rebekah Miracle, AERA GIS.



- Sockets
- Rock Cut Holes
- Limestone/Quarry Blocks
- Quarry/Rock-cut Channels
- Quarry/Rock-cut/Court /Burial Cuts
- Platform Lines



Ashraf Abd el-Aziz points to the line between the pyramid court pavement and the platform on the east side of the pyramid. Amr Zakaria stands “on line” to the south. Mohammed el-Saidy, then Inspector of the pyramid, and an assistant stand in the background. Photo by Mark Lehner.

Dynasty builders happen to “flat-bed” a stone, they would cut the bedrock floor underneath, allowing them to pry the stone with thick wooden levers. These lever sockets track movements of heavy stone by the pyramid builders.

Pavement Props

We found curious pairs of small holes in the bedrock floor of the court (photo below right). The builders may have used



GDFS 2016 team members, from left to right, Joan Dash, Rebecca Dash, Glen Dash, Amr Zakaria Mohamed, and Eric Sperber. Team members not included in the photo: Mohamed Abd el-Basset, Mark Lehner, and Ashraf Abd el-Aziz. Photo courtesy of Windfall Films.

them, somehow, for setting the thick limestone slabs for the court pavement. They seem to relate to the rectilinear cuts that masons made in the bedrock floor to lay in the court pavement slabs. The slabs were odd shapes and sizes, and large, nearly half a meter thick. Khufu’s masons custom-trimmed one

A pair of small holes (bottom of view) within the emplacement cutting for a slab of the pyramid court pavement. *In situ* pavement exists in the background, abutting the pyramid platform on which the builders founded the casing. View to the north. Photo by Mark Lehner.



Lever sockets cut into the bedrock floor of the court along the northern side of the Great Pyramid. They allowed wooden boards to be placed under a slab to keep it elevated and to move it around until the slab was finally bedded. View to the north. Photo by Mark Lehner.





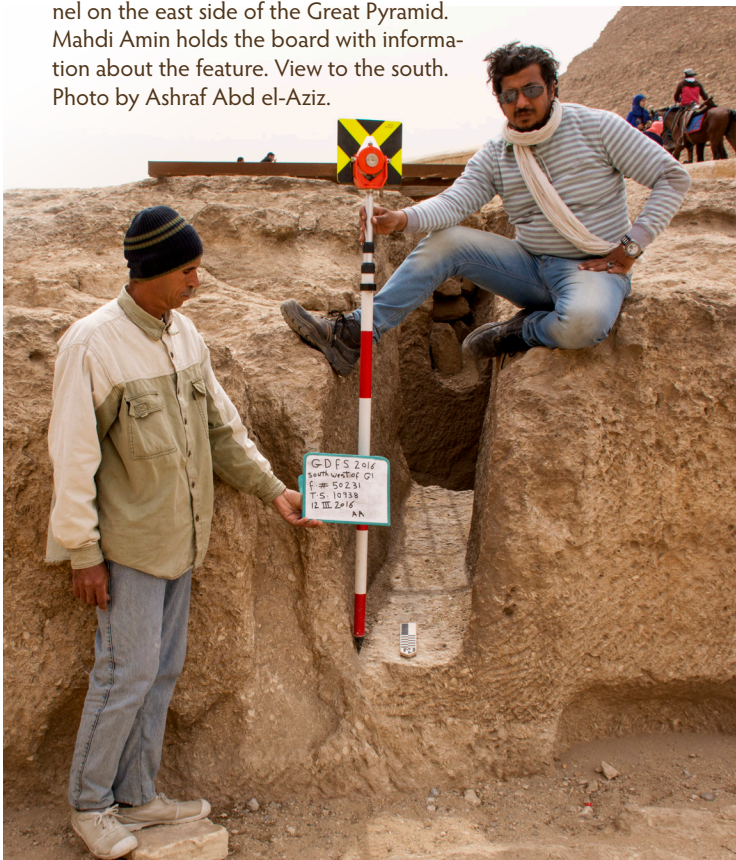
Joinery of court pavement at the northern side of the Great Pyramid. View to the north. Photo by Mark Lehner.

pavement slab to its neighbor, creating complex jigsaw patterns (photo above). Perhaps the masons inserted short wooden props into the pairs of small holes to keep the slab tilted up, close to its final position, as they cut its matching emplacement into the bedrock floor, so that when they lowered the slab, it would be close to flush with the slabs next to it.

Platform Alignment Holes

These large holes run in series parallel to the pyramid platform, 9.8 to 13.1 feet (3 to 4 meters) from the platform and 3 to 4 meters from hole to hole. Shorter series near the corners run in a line a little more than 16.4 feet (5 meters, around 5 Egyptian cubits) from the line of the pyramid platform. These holes vary

Amr Zakaria (right) holds a reflector over a quarry channel on the east side of the Great Pyramid. Mahdi Amin holds the board with information about the feature. View to the south. Photo by Ashraf Abd el-Aziz.



in shape, from rectangular to round, with sides ranging from 14 to 24 inches (35 to 60 centimeters) and depths varying from 16 to 24 inches (40 to 60 centimeters). The going hypothesis is that these holes held wooden posts, wide enough to carry a reference line, perhaps marked with string tied to nails in the tops of the posts, and that from this reference line the pyramid builders set and trimmed stones to form the platform and the casing. Now that we have surveyed and mapped these holes, we can test this hypothesis. We will be able to see if altogether they span a margin of a single, straight line that is as well oriented to the cardinal directions as the line of the platform (photo facing page top left).

Builders' Successive Approximation

Setting and trimming the pyramid platform and the baseline in the casing was probably the final operation of Khufu's pyramid builders, after they had leveled the overall pyramid court by cutting down the original rough, sloping bedrock surface of the Giza Plateau. We mapped and recorded—for the first time ever—evidence of first levelling stages of Khufu's builders, that is, their crudest quarrying to dress down the surface. We also mapped the quarrymen's channels that define the bedrock blocks near the southwest corner of the pyramid, where they left the blocks un-extracted.

Across the modern road from the pyramid, Khufu's quarrymen left an example of their earlier and higher stage of quarrying to cut the surface down to the level of the pyramid court. Here, their quarry blocks and channels are neither rectilinear nor oriented to the cardinal directions (red lines on map). They simply wanted to waste away the bedrock, to work it down several meters, without regard for orienting their quarry cuts. Next, on the east side of the modern road, closer to the pyramid, they left a later, more advanced stage of working down the surface (photo on the left). Here, they aligned their bedrock blocks and channels to the cardinal directions, as they got closer to the level of the pyramid court, which they wanted to be square and oriented exactly north-south and east-west.

The main (reference) line holes, parallel to the pyramid platform, reflect Khufu's builders' final operations in a procedure of successive approximation.

Since they left a colossal chunk of bedrock projecting in the base of the pyramid core, they really only achieved their finest levelling over the width of a city sidewalk, around the perimeter of the core. With successive approximation they created the near-perfect base of the pyramid, a bit more like sculptors than brick and mortar masons. As different as this is from how modern engineers and builders might make the Great Pyramid, they did a damn good job, a job that is the marvel of modern engineers and builders.

1. http://www.hip.institute/press/HIP_INSTITUTE_CP9_EN.pdf