Describe how the Pyramid of Khufu at Giza was Built. You can specialise in your answer, for example, by describing how specific stone materials were procured and supplied to the site, or how the chambers were aligned over each other so accurately.

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Synopsis

The Great Pyramid of pharaoh Khufu was built in the 4th Dynasty on the Giza plateau. A number of mysteries surround the Great Pyramid as there are no records detailing how the monument was actually built, yet the archaeological record has left some clues. The workforce of the pharaoh was made up of normal Egyptians who worked together under the guidance of ancient specialists, to produce an everlasting memorial to their king. Great care was taken in the alignment of the pyramid, aligning it with amazing precision by the northern stars. The labourers moved giant stones across the land, using a combination of external and internal ramps. They steadied the stone turning rooms of the internal ramp with thick courses, allowing the Egyptians to raise the stones up the dizzying heights of the Great Pyramid. Working together, the ancients built for eternity.

How the Pyramid of Khufu at Giza was built

The Great Pyramid of Egypt has survived the test of time. Built in the 4th Dynasty by the pharaoh Khufu, the pyramid reaches 146 metres in height, and contains over 2 million stone blocks. The chief architect was Hemiunu, “Overseer of All Construction Projects of the King, king's son of his own body” (Romer 2007, p. 86) who built this great monument to raise the king to the heavens with the gods (Isler 1987, p. 110). His actual methods, however, are a mystery. From simple deduction, the building of the pyramid involved a vast amount of manpower and meticulous planning. The builders aligned the Great Pyramid to face true north. They not only manoeuvred giant stones, but they defied gravity to create a man-made mountain of large blocks reaching up to the sky. Although there are still mysteries remaining about this amazing structure, the ancient Egyptians found a way to overcome these problems, and built the magnificent structure that is truly a wonder of the world.

The Great Pyramid could never have been built without specialists organising and performing tasks with great precision (Jacobs 2002, p. 6). “To complete the pyramid complex in the King's lifetime, a constant supply of material, labor and food was needed” (Jacobs 2002, p. 2). Planning, organisation and attention to detail was paramount. Management and specialisation was required to accomplish this. Specialists were in charge of the day to day lives of the pyramid labourers; absentee records, from illness to hangovers, have been discovered (David 1986, p. 74). Specialist titles included “the official in charge of one side of the pyramid” and “overseer of the stone movers” (Bronner 1993, p. 25). Physician-priest specialists were on hand to look after injured workers (Hawass 2004, pp. 22-23). The administration was performed by scribes who “recorded the day of transport, the workmen in charge, the stage of the transport, and the purpose for the stone (approximate placement) ... [and] included schedule, team, and action information” (Jacobs 2002, p. 5). Other specialists would have included recruiters (“inspector of young recruits”), stone haulers, stone setters, architects, masons, carpenters, sailors (“overseer

of the boat of Neith"), metal workers, craft workers ("overseer of craftsmen") and priests ("priestess of Hathor") (Hawass 2009 p. 16-17; Jacobs 2002, p. 5). The bulk of the heavy lifting, though, was performed by a large labour force.

Although the way the labour force was raised is uncertain (Romer 2007, p. 133), the graves of the workers have been excavated. The Upper Cemetery at Giza, near the 'Wall of the Crow' to the southeast of the Sphinx, contains the tombs of the workers. The male and female bodies discovered in the tombs have evidence of stress related to carrying heavy objects; yet they also prove that highly skilled physicians worked on these people, as there is evidence of people living for years after brain surgery, broken bones and amputation (Hawass 2004, pp. 22-23). Although, according to Lehner, their lives were based on a feudal system, they lived in the Giza city which was well equipped to feed the workers (Shaw 2003, pp. 47-49 & 99) and look after their daily needs. Jacobs (2002, p.4) calculates that 20,000-30,000 workers would be on site at once. Graffiti shows that the workers themselves were split into crews of 2,000. The crews were then divided into two gangs, and then into five tribes. Ganges had their own names (Shaw 2003, p. 99), some of which have been found graffitied in hidden places in the Great Pyramid (Hawass 2009, p. 15). These people were highly valued workers, who used both their skills and bodies towards building an everlasting monument to their pharaoh.

It was left to the astronomer-priests to perform one of the most important tasks, that of aligning the pyramid. They aligned the Great Pyramid to face north by using the stars (Jacobs 2002, p. 3; Spence 2000, p. 321). The orientation of the Great Pyramid is almost exactly true north: the west face is 2'30" west of north, the east is 5'30" west of north. As for the other faces, the north is 2'28" south of west, and the south is 1'57" south of west (Isler 1989, p. 191). When directionality was calculated, "evidence suggests that double rows of poles were set up and lines were extended between them" (Jacobs 2002, p. 3). According to Spence (2000, p. 324), this alignment indicates that Khufu's pyramid was laid in 2478 BC.

One foundation ceremony, mentioned on the 5th Dynasty Palmero Stone, is the three phase 'The Stretching of the Cord' ritual (Greenwell 2005, p. 3; Maravelia 2003, p. 67). In the first stage, the four corners of the construction were fixed by the stars with a notched palm stick and plumb lines. The second stage involved a cord, tied around stakes which had been placed at the four corners of the foundation; “I have grasped the stake along with the handle of the mallet. I take the measuring cord in the company of [the goddess] Seshat. I observe the progressive movements of the stars” (Belmonte 2001, pp. S6-S7). The final stage involved pushing the cords down onto the ground, which revealed where the foundations would be dug (Greenwell 2005, pp. 3-4). The stars used for the first phase were probably aligned to two stars: β-UMi (Kochab) in Ursa Major and ζ-UMa (Mizar) in Ursa Minor (Romer 2007, p. 350; Spence 2000, p. 322), see Figure 1. Yet further planning of the Giza complex had to be done before construction could begin.

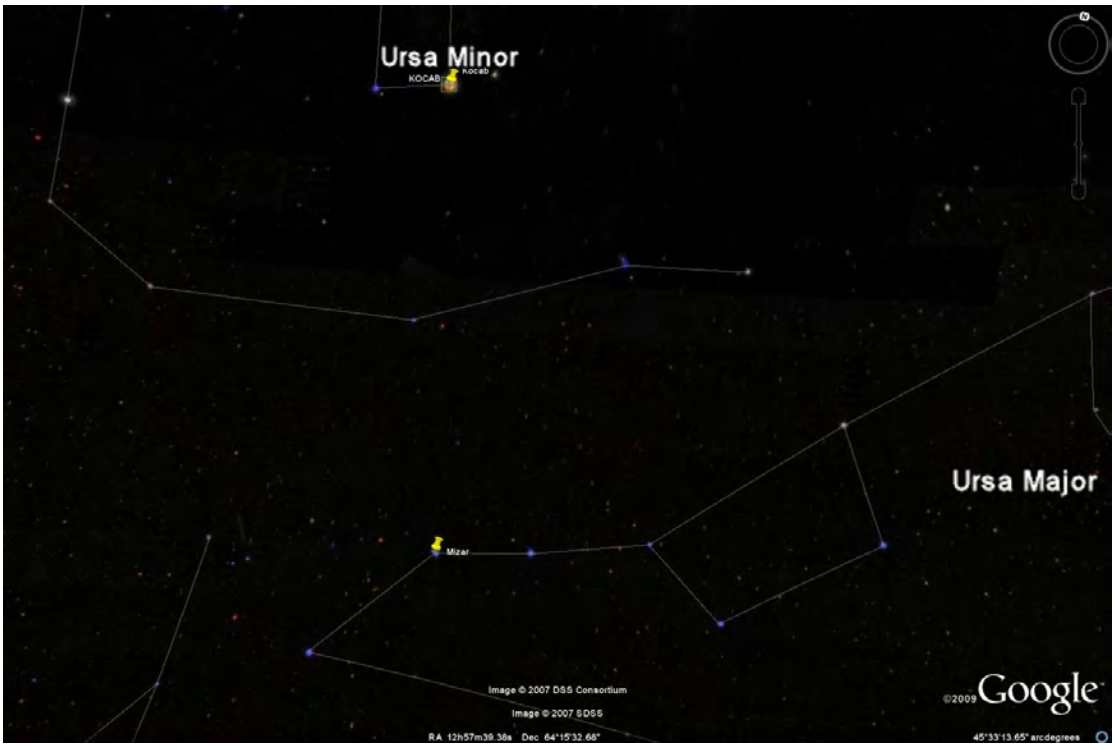

Figure 1: Kochab above and Mizar below, marked with yellow pins, in the constellations of Ursa Minor and Ursa Major. (Google Sky 2007)

Meticulous planning before construction was a necessity for the ancient Egyptians. Before construction, one of Khufu's satellite pyramids was shifted some metres to the west, moved so as not to interfere with the tomb of Queen Hetep-heres, and to allow for the mastaba of prince Ka-wab, suggesting that the whole pyramid complex was founded during the time of Khufu's reign (Smith 1942, pp. 523-524). The plan of the three pyramids of Giza must also have been pre-conceived, as the alignment of the three main pyramids aligns perfectly with the stars of Orion's belt: Mintaka, Alnilam and Alnitak (Brophy 2002, p. 68-70), see Figure 2. The ancient Egyptian world of the dead encircled Orion (Belmonte 2001, p. S4), and the correlation of the pyramids to Orion's belt was a direct link to the Egyptian netherworld. The ancient Egyptian religion, their concept of duality (Wilkinson 2001, p. 199), the planning, alignment and placement of the pyramids were therefore inextricably linked.

Figure 2: Orion's belt superimposed over the three pyramids of the Giza plateau (Brophy 2002, p. 68; Google Earth 2009; Google Sky 2007)

After the layout had been confirmed, the workers had to move heavy stone blocks weighing up to 16,256 kg with only basic equipment. To do so, they had rope, levers, rollers, sledges and rockers at their disposal (Arnold 1997, p. 268-280). One clue is the 12th Dynasty image from the

tomb of Djehutihotep. This shows a giant statue, approximately 53,000 kg, being pulled on a sled by 172 men (Jacobs 2002, p. 4), see Figure 3. According to Djehutihotep's inscription, he “let a troop of recruits come to prepare the road for [the statue], together with a team of stonemasons from the quarry, and the leaders with them were learned ... This statue came from the mountain as a block of exceedingly great weight” (Nederhof 2009). A man stands on the sled, pouring liquid in its path, presumably to reduce friction. With lubricant, it is much easier to start such large weights moving; eight workers is all that would be required to start moving a casing block of 2,750 kg on a flat surface (Stocks 2003, p. 576-577). The ancient Egyptian workers used a variant of this, pouring water over shale to make it slick (Romer 2007, p. 206), to drag giant stones to Khufu's pyramid.

Figure 3: Scene in the Tomb of Djehutihotpe at Deir el-Bersha (copied by John Gardiner Wilkinson before 1856). (Baines & Málek 1992, p. 126-127)

The builders of the Great Pyramid were of the methods of other builders of their time (Isler 1987, p. 87), so other buildings of the 4th Dynasty can be used to assess how Khufu’s pyramid was built. At the northern pyramid of Dahshur, the construction roads leading to the pyramid stops within 140 metres of the site, which is an indication of a very short ramp (Isler 1987, p. 95-96). At the unfinished mortuary temple of the 4th Dynasty pharaoh Menkaure, a mud ramp with an angle of 7° was left when work was abandoned. Experimental archaeology “revealed significant

advantages in moving stone blocks, and loaded sledges, along mortar- and mud-lubricated horizontal surfaces, and suggest an optimum of around seven degrees for a lubricated ramp" (Stocks 2003, p. 577). As the bottom quarter of the pyramid contains over half of its volume, the largest stones would be brought via a short, external ramp and the lesser stones moved by other means (Isler 1987, p. 96). The core of the pyramid was filled out with large stepped stones, judging from the construction of Khufu's queens' pyramids, and that of Menkaure and his queens (Isler 1985, p. 132; Isler 1987, p. 98; Rigano 2004, p. 3), and finally the casing stones were placed on top of the core.

To build the pyramid within the reign of Khufu, the Egyptians had to raise nearly 5,500,000,000 kg of stone, using a ramp, at a rate of approximately 5 stones per minute per Egyptian work day (Romer 2007, p. 197). Romer notes that, to have raised the stone to the various layers of the pyramid as it was being build, the construction ramps had to be "continuously modified, demolished and rebuilt to reach the ever-changing, ever-diminishing building site atop the ever-rising Pyramid" (2007, p. 200). In this vein, Bob Brier, American paleopatholigist, highlights a new theory by French architect Jean-Pierre Houdin; that an internal ramp, approximately 2 metres wide with a corbelled roof (Houdin 2009, pers. comm. 13 October), was used to drag stones to the growing higher levels of the pyramid. The internal ramp was cannibalised from an external ramp earlier used for building the lower part of the pyramid (Brier 2007). One piece of evidence for this theory comes from the EDF Foundation image of a 1986 microgravimetry survey of Khufu's pyramid shows an area of less dense material spiralling behind the faces of the pyramid (Bui et al. 1988), see Figure 4. This theory overcomes the problem of the architects being unable to see the pyramid itself as they were building (Houdin 2009, pers. comm. 13 October; Isler 1985, p. 129).

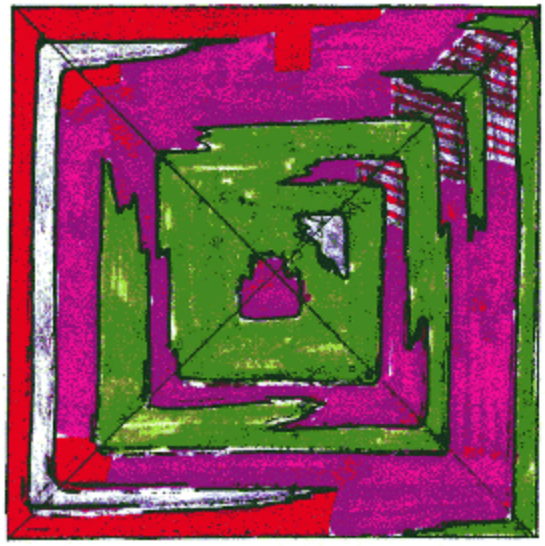

Figure 4: In 1986/87, nearly a thousand microgravimetrial measurements have been taken thanks to the EDF Foundation. A particular anomaly relating to the pyramid's density was thus revealed. (Brier 2007)

According to Brier, one clue relating to the internal ramp theory is the notch approximately 82 metres up on the northeast corner of the pyramid houses a purpose-built large room, about 3.3 by 1.5 metres and 2.5 metres high. “Some of the stones supporting the ceiling were cut into partial arches, and one block was clearly set in place as a keystone to complete the ceiling. This indicates that the room was planned” (Brier 2009). Houdin (2009, pers. comm. 13 October) wondered what a room that size and shape would be doing inside the pyramid wall. Brier (2009) believes this to be a place where the large blocks on their sleds were turned 90º, so that workers could continue dragging them up the ramp. The Secretary General of the Egyptian Supreme Council of Antiquities, Zahi Hawass, wrote in the foreword of Houdin's book that the theory is certainly worth considering (Houdin & Hawass 2006).

Another unusual feature of the Great Pyramid is that thicker courses were introduced at certain layers of the building. Originally noted by Petrie, he states that at “...the level of the King's Chamber signalizing where the area was a simple fraction of ½ of the base area, thicker courses were perhaps intentionally introduced where the area of the course was a multiple of $\frac{1}{25}$ the base

area: this system accounts for nearly all the curious examples of a thick course being suddenly brought in, with a series above it gradually diminishing until another thick course occurs" (Petrie 1883, p. 221), see Figure 5. These larger courses, though not completely regularly spaced, are at an average of 6.7 metres apart. Above thick courses, the stones diminish in size until another large course is introduced. Again, this was something done purposefully by the builders. These layers are courses of projecting stone from which to distribute other stones (Isler 1985, p. 134).

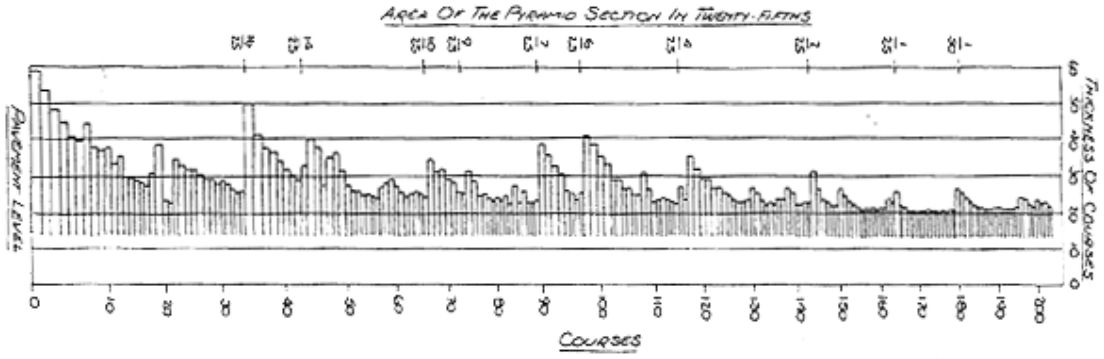

Figure 5: The incremental course thickness of the Great Pyramid. (Isler 1985, p. 134)

Putting these two theories together, the thick courses may have projected inwards on which to build the block turning rooms. The thicker courses would serve to both stabalise the rooms and allow for stone distribution around the pyramid. Houdin wrote, "I don't *think* that there is any correlation between the notch in the northeast corner of the Great Pyramid ... [with] the thicker courses" (2009, pers. comm. 13 October), but more research is required to see if the room behind the notch rests on one of the thicker courses.

The Great Pyramid stands today, thanks to the efforts of the industrious ancient Egyptian people. Khufu had access to a very large workforce, including specialists such as the astronomer-priests who aligned his pyramid by the stars. He had his pyramid built by his people, who lifted heavy stones to unbelievable heights. Working together, the people created a monumental masterpiece for their king to last through the ages. The Great Pyramid of Khufu, the epitome of the pyramid age, is a true testament to ancient skill of the ancient Egyptian people.

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