New Theory on Egypt's Collapsing Pyramids

By Peter James

Figure 1: The Step Pyramid.

The author's first introduction to working in Egypt was a project in Cairo's historic old quarter following the 1992 earthquake that caused widespread and devastating damage. Cintec International began working on a contract to repair and reinforce a number of badly affected structures, including some 15 notable mosques and maqaads, which were strengthened using the firm's patented anchoring systems. Following success in the old quarter, the focus moved to the internal reinforcement of the Temple of Hibis in the El-Kharga Oasis, 700 kilometres (434 miles) due south of Cairo. Construction on the Temple began in 672 BC, but unlike most other comparable structures, it had differential settlement problems due to poor soil conditions. Work on these buildings was completed with no damage to the splendor and history of the monuments.

Soon afterwards, Cintec undertook its first pyramid restoration projects. These involved strengthening the connecting burial chamber corridors and ceilings of Egypt's Red and Step Pyramids. The Red Pyramid is the third-largest of Egypt's pyramids and was the first "true" pyramid built by Pharaoh Sneferu. Sneferu had built two previous pyramids, but these were not of a true triangular shape, and for structural reasons were not chosen by the Pharaoh as his final resting place.

While work on the Red Pyramid was confined to strengthening the granite slabs immediately above the burial chamber's corridor, Cintec's next project, the Step Pyramid (*Figure 1*), required more careful planning and execution due to the very dangerous condition of the burial chamber ceiling. A large portion had collapsed during the 1992 earthquake, and what remained – a ragged, hanging, inverted group of large and small stones set in mud – was liable to collapse at any time. Cintec used its unique WaterWall airbags to support the ceiling temporarily without provoking further stone fall, before beginning work on final anchoring processes which are now halfway to completion. These ongoing projects offered insight into the nature of the pyramids' structural deterioration.

The Bent Pyramid

On one of the author's visits to the Step Pyramid, he was asked for an opinion on securing the remaining outer cladding of the Bent Pyramid (*Figure 2*), another construction by Pharaoh Sneferu, located 40 kilometers south of Cairo. This pyramid's top section sits at a slightly different angle to the main body, giving the structure its "bent" appearance.

Before any structural restoration work could be considered, the exact nature of the pyramid's defects had to be established so that the correct intervention could be carried out. From a visual inspection, the structure showed distress along all of its extremities (*Figures 3* and *4*). What were the clues? The pyramid did not appear to have any foundation movement. All of the missing cladding occurred at interfaces or changes of direction at the angles and between the ground and the cladding.

A popular theory is that the missing cladding was removed by local opportunist thieves. At the lowest levels that could be the answer, but the same condition occurs at higher levels and in an apparently random manner, with no signs of indentations from temporary scaffolding or of any symmetrical cutting of the blocks to aid removal. It would have been extremely dangerous work. To dismantle a structure, you normally need as much scaffolding as you would to build it, and opportunist thieves would hardly have had sufficient resources. Indeed, if they merely wanted rough stones, they could have found them in the hills adjacent to the center of Cairo without the trouble of removing and transporting them 30 miles out of town. The damage here appears to be caused by a giant whose hand has swept across the face of the pyramid with enormous energy, sucking out the facing and leaving the ragged empty sockets.

It is the author's belief that in the case of the Bent Pyramid – in fact, in the case of all pyramids – the outer casing has been affected by thermal movement. The Bent Pyramid is the only one with any degree of stone casing still attached, making the mechanism of failure apparent. The distress at all of the perimeter edges suggests that the outer casing has expanded from the center outwards, and movement has taken place on all of the extremities.

Figure 2: The Bent Pyramid.

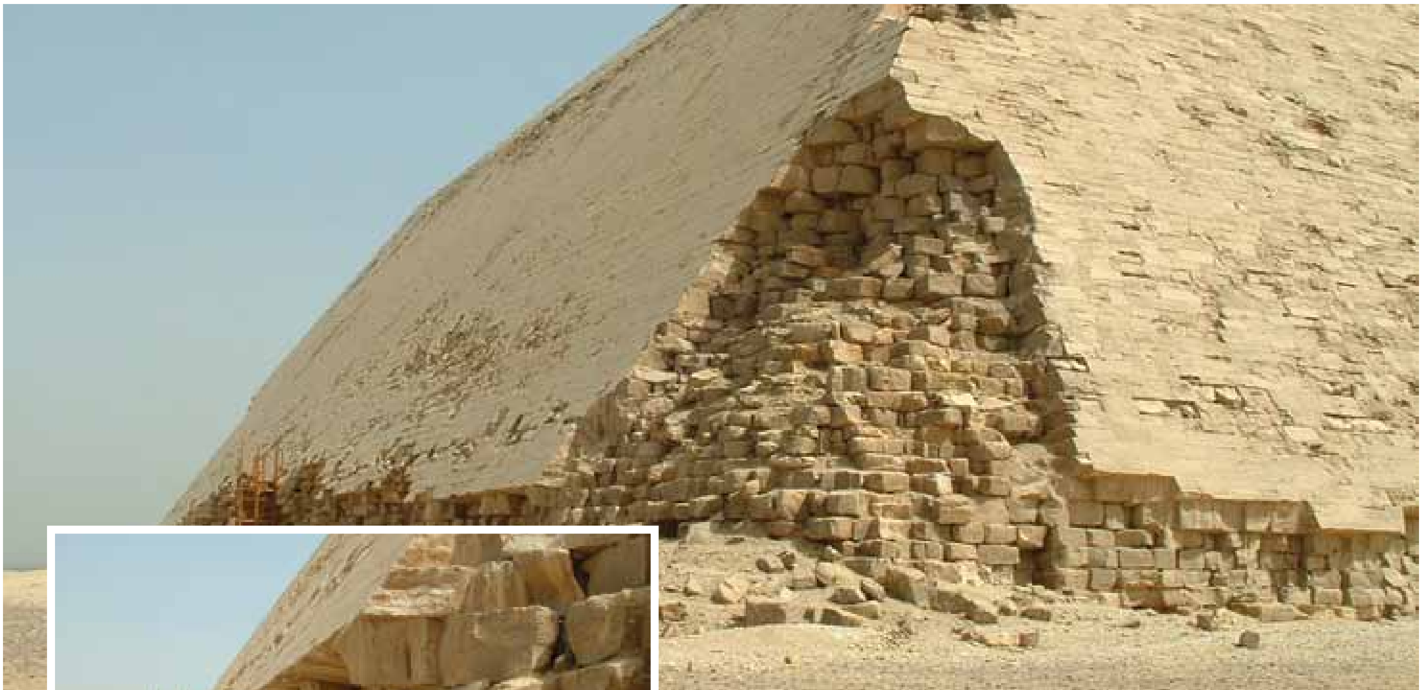

Figure 4: Limestone blocks cantilever out, where cladding below is no longer present, and eventually fail.

Figure 3: Major cladding damage at one corner of the Bent Pyramid.

It has been suggested that the original dimensions recorded by Flinders Petrie were inaccurate and that the dimensions taken in 2004 were larger by a small degree. This is to be expected of a structure that is still moving and increasing in size. Furthermore, the convex shape of the pyramid's outer casing could be caused by the stones arching between fixed points. The transit of the sun across the region will vary over the seasons, heating one side more than another, giving rise to disproportionate movement, particularly at the extremities.

Temperature Variation

During the day, the temperature rises to 40^{0}C (104^{0}F) across the face of the outer casing, then at night cools to 3^{0}C (37^{0}F) because of the lack of cover and exposure to the prevailing winds. This gives an average daily temperature fluctuation of 37^{0}C (67^{0}F). The photographs of the Bent Pyramid show how thermal expansion has caused the blocks to move to the edges, where they have detached. It also shows how individual stones, unsupported, can cantilever and snap off and subsequently fall to the ground.

Limestone has a coefficient of thermal expansion of $8x10^{-6}$, proportional to the change of temperature and to the original dimensions. Applying this yields ($8x10^{-6}$) x (37^{0}C) x (100m) = 30mm (1¼ inches) of movement per 100-meter (328-foot) run in all directions, although this is also dependent on the size of the gaps between adjacent stones. All movement from the thermal expansion of the casing would be taken up initially in the joints, but would also cause dust and stone particles to detach from the stones, filling the voids and gaps between them. This would reduce the amount of contraction possible at night, along with the stones' natural propensity not to return to their original dimensions and position, and so the cycle would start again. Multiply this endless movement by the number of days that the pyramid has been erected and you have the reason why all the outer casing has moved to the extremities, where it has buckled or displaced against blocks moving in the opposite direction and then fallen off. It may then have been picked up by opportunists and removed from the site.

Additional Questions

Another important question to consider is this: Why does the Bent Pyramid still have half of its outer casing attached, while the Red Pyramid and the Great Pyramids at Giza have virtually none? I believe that this is due to the increased skills of the craftsmen, who developed more knowledge and precision as the process of pyramid construction developed. They became able to provide better accuracy, build quality, and jointing of the slabs. The Bent Pyramid was probably built with less care, and with more voids between the stones that acted like expansion joints. The casing blocks being inclined inwards at the base of the pyramid may have limited the expansion.

Finally, could the sight of the progressive damage to the outer edges of the pyramids, that would have taken place relatively soon after their construction, be the reason that – having spent so much time and energy constructing these wonderful monuments – the Egyptians changed their burial method to the Valley of the Kings?

While the author is keen to stress that this is his opinion, rather than evidential fact, he suggests that thermal movement led to the crumbling of these magnificent structures, and eventually to their discontinued use.▪

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