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In This Issue ...

How Pyramids Were Built

Where the Evidence and Lack of Evidence Leads

Charles Rigano

When building pyramids, the use of ramps to raise stone blocks would seem logical. With the bottom course complete, it seems likely that the builders would have piled sand against it to form a simple ramp and would have pulled blocks up the ramp to build the second course. And it makes sense that as the courses and the pyramid height increased, the ramp would have been made higher and longer. This leads to the idea that blocks may have been placed on sledges that were pulled by teams of men up ramps to the very top of the pyramid—either long straight ramps or ones that wrapped around the pyramid. Television programs and drawings in books show ramps being used to build pyramids in these ways. The use of ramps has become commonly accepted as fact.

THE RAMP EVIDENCE

Unfortunately, there is scant archaeological evidence to support this "fact." The following is all of the evidence for the use of ramps in building pyramids:

- While excavating Sekhemkhet's 3rd Dynasty pyramid at Saqqara, Zakaria Goneim identified traces of what he called "foot-hold embankments" on the exterior of the pyramid, intended to give workmen access to higher levels, and a construction ramp on the pyramid's west side that led to the pyramid's center (Goneim 1956, 71).
- The very small pyramid at Sinki, in South Abydos, has a ramp perpendicular to each face.[1]
- Traces of two ramps with bases 165 feet long were found at Lisht leading onto the 12th Dynasty pyramid of Senusret I (Arnold 1991, 87).

That is actually all of the physical evidence for the use of ramps, covering more than 700 years of pyramid building.[2] And even this evidence is questioned. Vito Maragioglio and Celeste Rinaldi believe the Sekhemkhet footholds and construction ramp were actually caisson walls and part of the pyramid itself (Maragioglio and Rinaldi 1963, 32). The Sinki pyramid at South Abydos was planned to be only 40 feet high and was probably built using methods more similar to the construction of mastabas than to the construction of the large pyramids. And the Senusret ramps, even at an extremely steep 15-degree angle, would reach only 44 feet up the 200-foot-high pyramid.

Pyramid sites are not bare of ramp-like structures. Excavations around pyramids have uncovered the remains of temporary construction roads used to bring material to the sites. Dieter Arnold provides a good summary of these ancient roads (Arnold 1991, 80–87):

- Red Pyramid, Dahshur: Two roads approach the Red Pyramid from the west and two roads approach from the east.
- Maidum: Flinders Petrie found a 13-foot-wide brick road approaching the pyramid from the southeast and another road about 1,000 feet to the south.
- Giza: George Reisner found a road leading from the quarries behind the Sphinx up to a place east of Khufu's subsidiary pyramids.[3]
- El-Faraun, South Saqqara: South of Shepseskaf's mastaba (El-Faraoun, the "Pharaoh's Bench") are two 1,000-foot-long transport roads.
- El-Lisht: Roads approach the pyramids of both Amenemhet I and Senusret I.

THE RAMP

Given that the use of ramps is so widely accepted, we should test the ramp theory to determine if it is feasible and reasonable, and if ramps should be found in the archaeological record. Without an actual sample to test, we will have to first create a ramp model.

There are two basic types of ramps: straight-on and spiral. While a 10-degree slope does not sound very steep, just walking up one is difficult; pulling a large load would be extremely arduous. Our

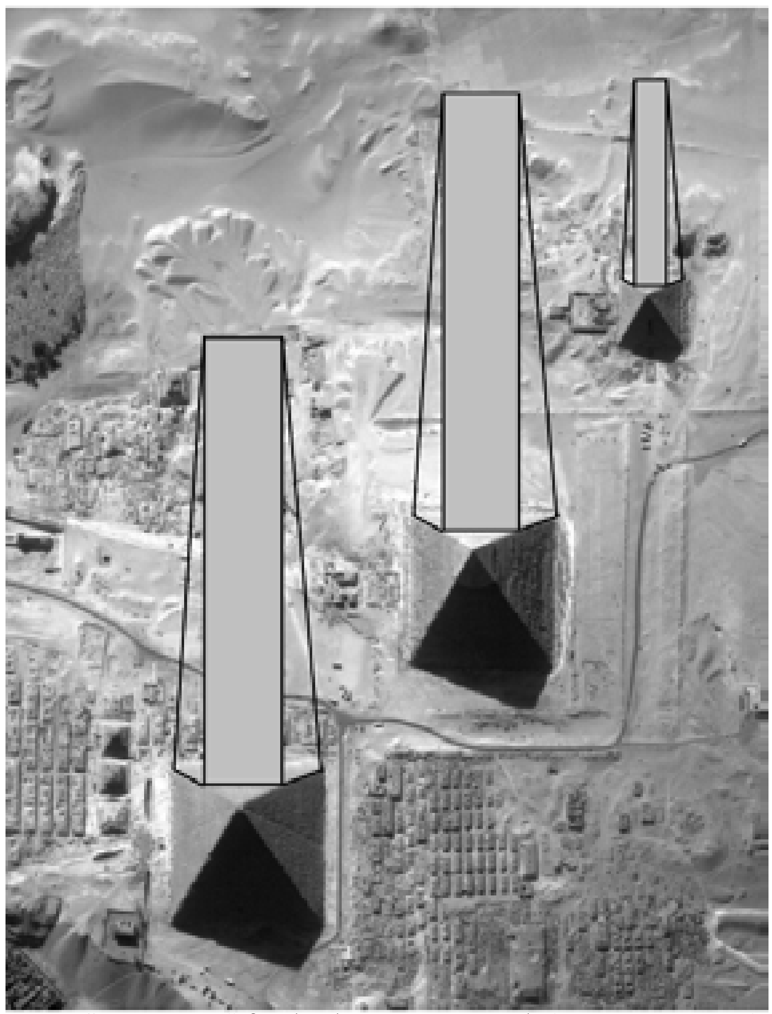
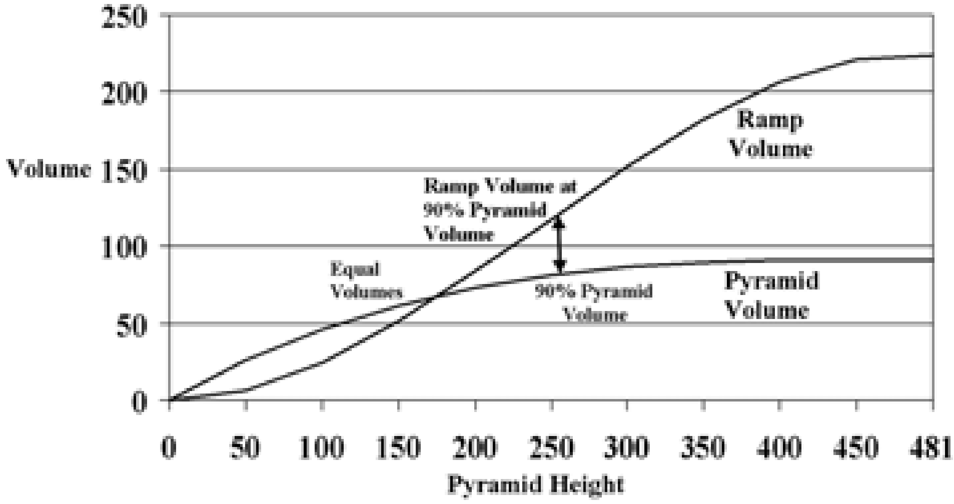


Fig. 1. "90% Ramps" for the three Giza pyramids (spaceimaging.com). North is at bottom.



Graph 1: Great Pyramid and Ramp Volume. When the volume of the pyramid reaches 90%, the volume of the ramp required to build it is 1.4 times greater. Height in feet, volume in millions of cubic feet.

hypothetical ramp has a 7.5-degree slope. For stability, the sides of the ramp would have to be approximately the "angle of rest" of the ramp material.[4] But if the sides were strengthened with rock and other materials, they could be steeper; for simplicity, we will assume pyramid incline, or about 52 degrees. In addition, the ramp would have to be wide enough to deliver massive amounts of material to the building platform and also provide space for the sledges and teams returning down the ramp to pass those going up.

When we apply the straight-on ramp model to the Great Pyramid, the result is a ramp which starts as wide as the pyramid base and which has its sides at the same angle as those of the pyramid. The ramp would always completely cover one side of the pyramid. As the pyramid grows taller, the ramp also grows higher and longer, while the upper portion of the ramp narrows since it is always as wide as the flat top of the pyramid. The primary benefits of such a straight-on ramp are the multiple lanes it provides to move material, no corners to move around, and the ability to control the pyramid's shape since three sides and all four corners are always exposed.

If built to the top of the pyramid, this ramp would contain 2.4 times more material than the pyramid itself.[5] But, building the ramp to the top would be unnecessary. In a pyramid, the volume is heavily concentrated near the bottom. In the 481-foot-tall Great Pyramid, the top 100 feet contain less than 1% of the entire volume.[6] The ancient builders must have realized that the resources to build a ramp to the pyramid's top would be out of proportion to the benefit realized. More reasonably, a ramp might have been used to about the halfway point, which contains 87% of the pyramid's volume, and then other methods would have been used to raise the remaining blocks to higher levels.

Initially, the volume of the ramp would be a lot less than the pyramid's volume. However, as the pyramid and ramp grow higher, the ramp volume approaches and surpasses the pyramid's volume (see Graph 1). The point at which both are of equal volume is when the pyramid is 178 feet tall and contains 75% of its final volume. However, this is not a reasonable stopping point for the ramp since there would remain more than 1.5 million blocks (of the total 3.9 million blocks) to raise higher.[7] So that we could proceed with the analysis, I picked a ramp 260 feet high, at which height the pyramid would contain 90% of its final volume (called the "90% Ramp"). This ramp would contain 1.35 times the final volume of the pyramid and would extend south from the Great Pyramid 1,976 feet or as far as Menkaure's causeway![8] Significant challenges would remain since the builders would still have had to lift more than 700,000 out of the total 3.9 million blocks to complete the pyramid above the top of the ramp.[9]

The 90% Ramp can be applied to other major pyramids (see Table 1). Even the smallest of the kings' pyramids, that of Unas, which has a volume of less than 2% of the Great Pyramid, would have a ramp almost two football fields long. At Giza, Khafre's ramp would stretch far to the south of Menkaure's pyramid, a long way from the major quarries.

Building these massive ramps slowly over many years would not pose significant challenges given that the necessary manpower was available. A problem not normally addressed in discussions of pyramid building is that the ramp had to be removed after the pyramid had been completed. Space for laborers to access the ramp and the length of the line between the top of the ramp and the dumping location would limit the number of people who could be employed in removing the ramp. Calculations show that our Great Pyramid 90% Ramp would take three years to remove.[10] While other pyramids would have ramps of significantly smaller volume, their smaller size would lower the number of people who could be effectively employed in removing the ramp material. Consequently, in these other cases, it would still have taken several years to remove the ramps.[11]

Pyramid	Pyramid Height (Feet)	Height to Contain 90% Volume (Feet)	Ramp Length at 7.5 Degrees (Feet)	Ramp Volume (000 Cubic Feet)
Maidum	302	164	1,243	30,667
Bent	345	187	1,420	52,484
Red	342	185	1,408	60,234
Great Pyramid	481	260	1,976	124,258
Khafre	472	256	1,943	111,872
Menkaure	215	116	885	11,326
Userkaf	161	87	663	4,416
Sahure	155	84	638	4,412
Neferirkare	241	131	992	14,861
Neuserre	165	89	679	4990
Unas	141	76	580	2,684
Dynasty VI	172	93	708	5,438

Table 1: 90% Ramp Dimensions for Various Pyramids

Section	Height Reached (Feet)	Section Length (Feet)	Section Width (Feet)	Slope (Degrees)	Blocks Remaining
Quarry to SW Corner	0–98	1,050	98	6° 36′	
West Face	98–203	820	98	7° 18′	2,510,000
North Face	203–312	590	65	10° 23′	1,252,000
East Face	312–387	328	65	12° 57′	381,000
South Face	387–436	197	65	14° 2′	77,000
West Face	436–481	131	65	18° 39′	5,000
Total		3,116			

Table 2: Mark Lehner's Spiral Ramp[12] (Lehner 1985, 129–132)

SPIRAL RAMP

A spiral ramp starts closer to the pyramid and winds around the pyramid's sides. It sits on the pyramid's face, using the pyramid to form part of the ramp base, and therefore has significantly less volume. Mark Lehner described such a possible spiral ramp for the Great Pyramid, which would have run 1,050 feet from the quarry to the pyramid's southwest corner and then wrapped around the pyramid 1¼ turns before reaching the top of the pyramid.

There are significant problems associated with a spiral ramp:

- There is no archaeological evidence to support its use.
- The ramp would have covered all four faces and corners making it extremely difficult to keep the pyramid aligned properly as it was built.
- Even using the pyramid as part of its base, the ramp's volume would still have been about half of the pyramid's volume.[13]
- Almost 400,000 blocks would still have had to be pulled up the top portion of the ramp, which would have an angle of 13 degrees or greater.
- Because the ramp would have to have been removed from the top down, and due to the limited space on the ramp, it would have taken on the order of eight years to remove.[14]

These negatives are too great, and with the lack of any supporting evidence there is no reason to consider this type of ramp any further.

SOME PRACTICAL PROBLEMS

In a separate article, I proposed that pyramids were built in two stages (Rigano 2003, 2–7). First, an interior step pyramid was built, atop which was placed an apex marker for the final inclined pyramid. Then the inclined pyramid was built around the step pyramid. This would have necessitated building a large ramp for the interior step pyramid, removing that ramp, constructing a second ramp for the inclined pyramid, and removing that ramp. Included in this process would have been significant effort to build the two ramps and many non-productive years while the ramps were removed.

Even if this double-ramp explanation for building a true pyramid is incorrect, there are several pyramids that would have required multiple ramps for their construction, if ramps were used at all. The Maidum Pyramid was completed twice as a step pyramid and a third time as a true pyramid (Lehner 1997, 97) which would have required the building and removal of three ramps. Maragioglio and Rinaldi proposed that the Bent Pyramid was initially started at a 60-degree angle and then the angle of the upper portion was reduced to 54 degrees. This would have required the construction and removal of two ramps without even considering how and when the part above the bend was built. Djoser's Step Pyramid was modified five times (Edwards 1993, 35–97), requiring the building and removal of many ramps. Any type of ramp—straight-on or spiral—would have been impractical.

WHERE IS THE RAMP EVIDENCE?

While *lack* of evidence is not normally considered evidence, with so much excavation around the pyramid sites and so many construction roads found around the pyramids themselves, certainly it seems highly probable that if ramps were used to build the major pyramids, some remnants of them would have been found.

The 90% Ramp I proposed would not be short[15] and would have extended far outside the pyramid complex. While remnants of a ramp to the south of the Great Pyramid might have been largely destroyed by later quarrying and buildings, ramps for Khafre's and Menkaure's pyramids (Fig. 1) would probably have been built from the south or west where there was little later construction. The Maidum, Bent and Red pyramids were built in the desert, sparsely populated by other structures. If they had been built with straight-on ramps, those ramps would have been up to 1,400 feet long. Even a spiral ramp, comparable to the one Lehner described for the Great Pyramid, would have extended the length of a football field from Unas's small pyramid and more than twice that far from the Maidum, Bent and Red pyramids.[16] Yet there is no evidence of a construction ramp anywhere around any major pyramid; they have not been found during excavations, there is no surface evidence, and there are no shadows of them on aerial photos.

To summarize the lack of evidence for the use of ramps:

- Ramps well over 700 feet long would have been common whether considering straight-on or spiral ramps. These ramps would have extended well beyond the pyramid complex. It is unlikely that, at every pyramid, all evidence of such a ramp would have been removed so completely.
- There are no traces of ramp remnants for pyramids that were either never used or were completed after the king's death such as Maidum, Abu Rawash and Menkaure's pyramid. With the focus turning to the new king, it would be extremely unlikely that these sites would have been so thoroughly cleared of ramp material.
- There have been no ramps or ramp remains found around incomplete pyramids such as the Layer Pyramid of King Khaba, Raneferef's pyramid, Neferefre's pyramid, or Menkaure's subsidiary pyramids.
- As we noted at the beginning of this article, while excavators have found bases for many construction roads, they have found no bases for major pyramid construction ramps.

Straight-on and spiral ramps have been theorized as a logical solution for raising blocks to higher pyramid levels. However, no evidence for their use in building large pyramids has been found, when evidence should be abundant. Therefore, the logically determined and almost universally accepted ramp theory fails.

THE OTHER CHOICES

While we have discounted ramps, we do need to recognize that millions of blocks were raised to high levels and that the ancient builders obviously had a reasonably efficient means to do this.

There are only a few other reasonably possible means to raise stone up the side of a pyramid. "Machines" employing counter-weights, wedges, fulcrums or levers could be placed on either a

Fig. 2. Left: The granite casing on the northern face of Menkaure's pyramid shows the excess material forming the bulbous face. The material is far more than needed to protect the final, finished face. Right: The dark granite blocks in Menkaure's mortuary temple have prepared faces with only edge protection.

stair-like structure built along the pyramid's sides or on each course. Multiple machines would be used to raise blocks one course at a time. Placing the machines on the pyramid itself would not work even if enough space were available on each course. To form a true pyramid, the builders would face the almost impossible task of placing the inclined casing blocks from the top down. If an exterior staircase were built, it would have to be of stone, and there is no evidence for such a thing. Other than Herodotus's 450 BCE writings on the use of machines based on highly questionable reports by locals, there is no evidence that machines were employed to lift blocks. In any case, the process would be painfully slow and extremely dangerous to people on levels below the machines when they broke. Thus, the machine theory also fails. This appears to leave only one possible method.

THE LAST CHOICE

Menkaure's mortuary temple was built with limestone walls which were intended to be covered by a granite face. Although the limestone walls were built, only a small number of the granite facing blocks were in place at Menkaure's death. Instead of completing the granite facing, Shepseskaf, Menkaure's son and successor, covered the granite blocks and completed the temple with a painted mud brick facing (Reisner 1931, 30).

Preserved under the mud brick were the granite casing blocks as they stood when Menkaure died. The blocks show they were largely finished in the work yard with only an outside, raised surface lip to protect the edges until the final preparation of the stones could be made.

The unfinished granite casing blocks on Menkaure's pyramid are different. They were brought from the work yard with the final pyramid angle cut around the block edges, but large bulbous projections were left on the outside face. The bulbous projections must have had a purpose; certainly the workmen could more easily have flattened the exterior face in the work yard than on the pyramid itself and, with the extra weight removed, the blocks would have been easier to move. Looking for other examples, we can find this same bulbous face on unfinished casing blocks on the south side of Menkaure's inclined subsidiary pyramid (GIII-a) and on Khufu's southern subsidiary pyramid (GI-c). Why the difference in the casing blocks?

This leads us to the only real choice left: Could these bulbous faces have been used to support material on the pyramid's sides? If material was packed on a pyramid's face to form a steep slideway, pyramid blocks could be pulled up this slideway from above—the "Pull-up Method." The bulbous casing face would have helped hold the packing material in place and would have protected the casing face. Blocks on sledges could have been pulled up the side of the pyramid by men or animals standing on the flat top of the unfinished pyramid.

Fig. 3. The granite casing to the south of GIII-a. The pyramid face fell at the arrow; all material to the right was excess.

Course	Average Block Weight (in pounds)	Number of Pullers (75 to 100 lbs per person)	Pull-Line Length (in feet, allowing 2 feet per person)	Top Surface Dimension (in feet, per course)
1 10	11,768	N/A	N/A	N/A
11-50	4,821	48–64	98–128	621 by 621 (30)
51-100	2,964	30–40	60–80	443 by 443 (75)
101-150	2,194	22–29	44–58	268 by 268 (125)
151-200	1,405	14–19	28–38	119 by 119 (175)
201-218	1,123	11–15	22–30	24 by 24 (209)

Table 3: Feasibility of the Pull-up Method[19]

In the Great Pyramid, the heaviest blocks are in the first few courses. In course 9 and below, the blocks range from three to twelve tons. Above that point, with only a few exceptions, the blocks become significantly smaller, averaging one to two tons, with the top 100 courses comprised of blocks that are generally less than one ton. The most reasonable use of the Pull-up Method would be to use short ramps for the heaviest blocks comprising the first nine courses, and then pull the higher, lighter blocks up the pyramid's side.

In order to test the Pull-up Method we need to ask the following questions:

1. Is it feasible: could the blocks have been pulled up, and was there enough room for the people to stand who were doing the pulling?
2. Would the block delivery rate have supported pyramid construction in a reasonable amount of time?
3. And, is the method supported by the archaeological record?

To address the first question, Table 3 describes the feasibility of the Pull-up Method. It shows that block weights decrease significantly at higher levels in the pyramid.

Calculations show that to pull a block up the the 52-degree side of the pyramid requires about the same force as lifting the block vertically.[18] Based on the weight, we can estimate the number of people needed to pull a block up the pyramid's side and how long the line of pullers would be. Table 3 shows that the dimensions of the square top of the pyramid are significantly larger than the pull-line length at every height, even near the top. At the very top few courses, with only fifteen 1,100-pound blocks remaining, the pull team could stand on the bulbous projections of the casing blocks protruding from the pyramid sides. The total number of people on the pull teams would not exceed 1,100.[19]

To address the second question, Table 4 considers whether blocks could be delivered up the pyramid at a sufficient rate to complete the pyramid in a reasonable amount of time. For this analysis, the height containing half the pyramid volume is used since below this point the delivery of blocks would be at a higher rate and would be at a lower rate above this point. The result is a surprisingly short 8.8 years to complete the pyramid. Even if the factors were changed and the time doubled, a span of 17.6 years would provide an acceptable construction time.

Pyramid height which contains half of the 3,923,000 blocks	Course 54,150 feet high
Dimensions of the flat pyramid top at this height	520 by 520 feet
Width available for raising blocks, given that half the width is needed for lowering sledges	260 feet
Number of lift lanes at 20 feet each	13
Time to raise a block at 1 mile/hour to 150 feet	1.7 minutes
Estimated time per block to raise each block, given hook-up, un-hook, and rest time	6 minutes
Number of blocks raised by a team in 1 hour	10 blocks
Number of blocks that can be raised in a 10-hour day	1,300
Number of blocks that can be raised in a 340-day year	442,000
Number of years to raise 3,923,000 blocks	8.8 years

Table 4: Years to Raise Pyramid Blocks in Khufu's Pyramid

To address the third question, the following considers the archaeological evidence that would support the Pull-up Method:

- It requires no large structures that would leave remnants behind.
- There would be no monumental facilities, like ramps, to depict in overseers' tombs.

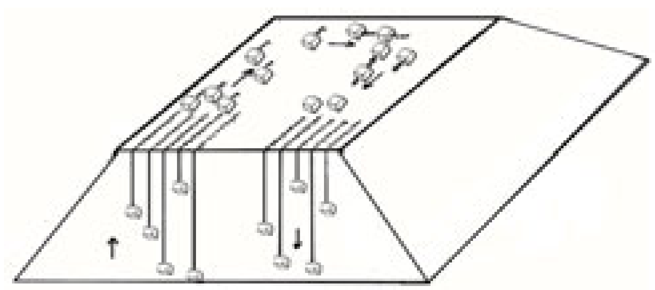


Fig. 4. The top of the Great Pyramid, completed to 200 feet, has a top surface area of 441 square feet. Blocks are pulled up the side on sledges, moved to the unloading point, and the empty sledges are lowered back down the pyramid.

- In the cases where a king died before his pyramid was completed, there would be only a thin covering of mud left over the pyramid's face which, if not removed manually, would be removed by natural forces.

Therefore, while the other methods would leave behind evidence, the Pull-up Method would leave nothing behind in the archaeological record, which is exactly what has been found: no bases for ramps, no piles of removed materials, no marks on the ground, no tomb drawings.

In summary, the foregoing evidence indicates the following benefits of the Pull-up theory:

- The method is feasible and can be completed within a reasonable number of years.
- There would be no large ramp to remove after a pyramid was complete, shortening the time needed to build it.
- The infrastructure necessary to raise blocks would be minimal, and minimal resources would be needed to maintain the pyramid's face covering.
- The minimal infrastructure is consistent with the builders' ability to make modifications to the Maidum, Bent and Step pyramids.
- The builders could conserve manpower by using blocks from very close-in quarries.

Recall that there is no archaeological evidence to support any of the ramp or "machine" theories. With the Pull-up theory, we have a method hinted at by the difference in casing blocks between Menkaure's Mortuary Temple and Pyramid. And, most importantly, the Pull-up Method is supported by the archaeological record.

ENDNOTES

1. See Lehner (1985, 217) for a picture. On page 96, Lehner identifies the intended base as 35 cubits (60 feet). Arnold (1991, 81) estimates the intended height as 12 meters (40 feet).
2. I have not included Zahi Hawass's discovery to the south of the Great Pyramid of two walls about 5 feet long and 5 feet apart. While these may have been related to the pyramid or the mastabas (cemetery GIS) just south of the pyramid, there is no evidence they were part of a great ramp lying against the side of the pyramid.
3. Oddly, Arnold (1991) describes ramp remains and has a photo of an area east of the Great Pyramid while the Reisner (1931) reference he uses describes a ramp well to the west of the Great Pyramid.
4. The "angle of rest" for loose sand is approximately 40 degrees.
5. The volume of the Great Pyramid is 91.6 million cubic feet while a ramp as described to the pyramid's top would contain 224 million cubic feet. (Based on Lehner 1997, 108.)
6. The pyramid's volume is 91.6 million cubic feet. The volume contained in the bottom 100 feet is 45.8 million cubic feet or 50% of the total. The volume contained in the bottom 380 feet is 90.8 million cubic feet or 99.1% of the total volume.
7. For this paper it was necessary to have a detailed estimate of blocks in the Great Pyramid by course. Therefore, I recreated Anthony Sakovich's calculation (Sakovich 2002, 53–57) of how many blocks are contained within the Great Pyramid. His total is 3,947,159 in 215 to 217 courses; using the same methodology, my calculation is slightly less at 3,922,760 in 218 courses.
8. Even a steep 10-degree ramp to the 260-foot level would be almost 1,500 feet long and go well past Khafre's Pyramid.
9. The remaining volume above course 102 is 8,804,373 cubic feet and would be composed of 712,443 blocks. Therefore the average block would be 12.36 cubic feet and weigh an average of 1,915 pounds (155 pounds per cubic feet for limestone). A block measuring about 2 x 2 x 3 feet would account for this volume.
10. Removing the ramp from the lower sides would create a serious slide danger as the base was removed and would put the labor force in jeopardy of being buried. The ramp would, of course, have had to be removed from the top down to avoid dangerous slides. Starting with 7,400 people and ending with 17,500 people, as greater access to the ramp surface became available, each person could make 20 round trips per day of 1 one mile each, carrying 0.5 cubic feet weighing 50–75 pounds.
11. It is possible that those pyramids were smaller because the king did not have the resources to build a larger pyramid and therefore the number of people available to remove a ramp would be proportionately smaller for these smaller pyramids.
12. The width of the initial section is stated as 30 meters. The remaining sections are estimated by measuring from the accompanying drawing.
13. The volume of the ramp would be approximately 47 million cubic feet.
14. Assuming the spiral ramp were removed from the top, because of the limited amount of space on the ramp an average of 2,378 people could be employed at a time in removing ramp material. They could make 14 round trips per day of 7,450 feet each, carrying 0.5 cubic feet weighing 50–75 pounds. Thus, the removal of a spiral ramp would take longer than the removal of a straight-on ramp.
15. The ramps would range between 580 feet long for the smallest major pyramid, Unas, and 1,976 feet long for the Great Pyramid.
16. With the first spiral ramp section rising to 25% of the pyramid's height and at the angle described by Lehner, this first section would be 301 feet long for Unas, 660 feet long for Maidum, and 748 feet long for both the Bent and Red pyramids.
17. The first nine courses rise 394" (32.8 feet). A simple ramp from the nearest quarry, 300 feet away, would be only 6 degrees.
18. The pulling force has to overcome gravity and friction on the ramp. The static coefficient of friction for wood on stone is 0.4 (Center for Advanced Friction Studies 2005) from which the kinetic coefficient of friction can be estimated at 0.3 to 0.35. Using this coefficient in calculating the force required to overcome gravity and to overcome friction (Kurtus 2005) at the Great Pyramid angle of 52 degrees shows that a 2,000 pound block on a sledge would require 1,946 to 2,007 pounds of lifting force, essentially equal to the weight of the block.
19. The maximum number of workmen employed in pulling blocks up the side of the pyramid would be where the flat pyramid top would be the widest. I have proposed a ramp to course 9. At course 10, about 40 feet above ground level, the flat top of the pyramid would be 692 feet wide (and long), providing space for seventeen 20-foot-wide pull-up lines and seventeen 20-foot-wide let-down lines. Using the 64 workmen in each pull-up line from Table 3, this provides a maximum of 1,088 people (17 x 64) employed in pulling blocks up the pyramid's side. At higher courses, fewer workmen would be employed since the flat top of the pyramid becomes smaller and the blocks lighter. Presumably, the stronger people would be used as the top is approached.

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THE TAUSERT TEMPLE:

An Additional Feature Discovered in the 2005 Season

Richard H. Wilkinson

An article on the first two seasons of the University of Arizona Egyptian Expedition's excavation at the Memorial Temple of Tausert in western Thebes[1] appeared in the last issue of *The Ostracon*.[2] This short note completes that summary now that the analysis and assessment of one last archaeological feature discovered late in the 2005 season has been finalized.

Our earlier summary showed how our work at the Tausert site has already demonstrated that W.M.F. Petrie's examination of the site in 1896 was quite superficial and that the site was clearly not systematically excavated, studied, or planned at that time.[3] Of particular importance is the fact that Petrie asserted that apart from the cutting of the foundation trenches and the installation of foundation deposits, only some initial building had been begun at the very back of the temple compound. Apart from inaccuracies in the plan published by Petrie, our first two seasons showed ample evidence of mud brick and worked stone across the surface of the site as well as the presence of large stone blocks in the foundation trenches where Petrie had said there were none—around the outer, courtyard area where he thought no building work had been initiated.

A final important clue that building was, in fact, initiated in a more widespread manner at the Tausert Temple was unearthed in our 2005 season and can now be reported. On May 24, while clearing the small surface units S16 and S17, which represent the ground surfaces of small chambers at the north side of the temple courtyard area (Fig. 1), we uncovered a patch of hard, well made flooring some 58cm by 84cm. This type of flooring is usually composed of mud mixed with gypsum or other materials to strengthen it and is identical to the type of flooring still used by many of the local people in their homes today—and called *dekka* by them. Later in the day we discovered another, larger section of this flooring some 2 meters by 1.9 meters preserved on the surface of the adjacent area S17. This patch of flooring ran up to the foundation trench and could be measured at about 6cm in depth.

The surface areas in this northern section of the temple court are so badly eroded that it is interesting that any flooring survived there at all, and it is likely that flooring was, in fact, built up on the underlying *gebel* bedrock in all the surface units (each representing a small chamber) on the temple court's north side.

This seemingly minor discovery has important implications for our understanding of the development of the Tausert Temple. Although unearthed in an area of extreme weathering where little of the original evidence remains, the extant flooring clearly shows that building work had progressed well beyond the very back of the temple into the courtyard area of this monument. The find is also important for its implication for the level of building actually achieved in the still unexcavated rear of the temple—where preliminary evidence suggests the cult may have been established.

ENDNOTES

1. As always, the UAEE would like to thank the Supreme Council of Antiquities for allowing its work in Egypt, and also acknowledges a number of supporters whose kind help made this work possible. Stephanie Denkowicz, Kathryn Michel, Dr. Bonnie Sampsell, and Donald and Edith Kunz are particularly thanked for their kind support of the 2005 season's work.
2. Richard H. Wilkinson, "The Tausert Temple Project: 2004 and 2005 Seasons," *The Ostracon* 16 (2): 7–12 (summer 2005).
3. See also Richard H. Wilkinson, "Excavation in the time of V.S. Golenischev: W.M.F. Petrie's work at the Tausert Memorial Temple," Invited Chapter for V.V. Solkin, ed., Memorial Volume for V.S. Golenischev (Moscow: Association of Ancient Egypt Studies [in press]).

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Fig. 1. Excavation of the area on the northern side of the Tausert Temple court where, despite weathering, sections of complet-ed flooring were found.

The Mortuary Temple of Hatshepsut at Deir el-Bahri: The Construction and Restoration of a Masterpiece–Part II

Bonnie M. Sampsell

[The following article should have been published as an integral part of Dr. Sampsell's article in the Summer 2005 issue of The Ostracon. *The Editorial Staff apologizes to Dr. Sampsell and our readers for our error. —The Editor]*

SUMMARY OF PART I

The first part of this article described the history of the temple through a number of phases.[1] The earliest construction phase is now thought to have begun early in the 18th Dynasty under the reign of Tuthmosis II. It drew its inspiration from the adjacent Middle Kingdom temple of Mentuhotep II. Under Hatshepsut, "her" temple was remodeled and expanded to the dimensions we see today. The temple structure was embellished with inscribed scenes and statuary featuring Hatshepsut. After her death, Tuthmosis III ordered Hatshepsut's statues destroyed, her inscribed figures obliterated, and her cartouches changed to those of his father or grandfather.

Although eclipsed in importance by later West Bank temples, Hatshepsut's monument continued to function through the Ptolemaic era, before being gradually covered by rocks falling from the cliffs. For several hundred years, a Coptic monastery occupied the site. In the 1800s, travelers and scholars began to uncover the ancient ruins and to unravel their story. This process of excavation and partial restoration continued under various expeditions in the first decades of the twentieth century.

WORK OF THE POLISH-EGYPTIAN MISSION

In the early 1960s, Egyptian authorities authorized a complete restoration of the Upper Terrace of the temple. President Nasser wanted a team from a Socialist (non-Western) country, and the Polish experts had a lot of experience in restoring their own historical monuments destroyed during World War II. Kazimierz Michalowski, the first director, was a highly reputed Egyptologist. He and other Polish specialists supervised Egyptian restorers for what became an extended joint mission.[2]

Over the years, excavations by a number of people had unearthed a vast array of architectural and inscribed pieces. Fragments from all three temples (those of Mentuhotep II, Tuthmosis III and Hatshepsut) had been discovered almost everywhere within the huge field of ruins at Deir el-Bahri.[3] Although some of these had been replaced, the Polish team found more than 10,000 pieces laid out in rows on the Lower and Middle Terraces of Hatshepsut's temple like parts of a gigantic jigsaw puzzle.[4] Years of careful research were necessary before any attempt could be made to reassemble the puzzle to its original condition. The first priority was to clear all areas, record and sort the fragments, and clean and consolidate pieces as needed.

Architectural engineers were employed to plan the restoration of the temple fabric with the goal of restoring the complete exterior of the temple. They were aided in their studies by archaeological evidence of the original ground plan and the architectural elements themselves. Comparisons with the structure and decorative motifs of other temples were also helpful.

The general approach has been to reincorporate as many of the original fragments of the temple as possible into reconstructed features. The shapes and dimensions of retrieved remains have allowed the architects to faithfully reconstruct walls, cornices and columns. The original temple walls were built with two outer faces of fine-grained limestone blocks joined with wooden cramps. The cavity between the two facing walls was filled with rubble into which the backs of some facing blocks extended to improve the bonding.[5] The reconstructed walls have a solid fired-brick core against which original inscribed facing blocks have been set. Missing facing blocks have been replaced with brick and overlain with a thin, artificial limestone facing (essentially a "tile" rather than a block).[6] These substitutes can be replaced with ancient stone fragments when they are identified. The distinction between new and old material is clear,

Fig. 1. Upper Courtyard looking towards southeast corner. Polygonal columns have been restored to various heights depending on the number of ancient fragments they contain. Some fragments of architraves are set on plinths (left front).

Fig. 2. Hatshepsut's Mortuary Temple at Deir el-Bahri lies beneath unstable cliffs of shale topped by massive limestone.

but subtle. Reinforced concrete has been used in invisible locations where extra strength is needed.

Before inscribed walls can be reconstructed, Egyptologists must study the fragments, find ones that match, and determine their position within the temple. It is like doing several gigantic jigsaw puzzles simultaneously without any pictures on the box! Fortunately, the restorers can draw on parallel scenes and texts located in other temples, including some dating to Hatshepsut's reign. Each year they make additional finds of matching pieces in the storerooms, and at the same time correct mistakes that earlier restorers made in their reconstructions.[7] Unfortunately, since the temples were used as quarries for over 3000 years, many pieces will never be found while some extant fragments cannot yet be linked to any other.

Some sections of Hatshepsut's temple have been rather fully restored, while in others—where only a small number of original fragments have been recovered—only a partial restoration has occurred. For example, only a handful of Osiride statues were reconstructed in the Upper Portico, and most columns in the Upper Courtyard are only a few feet tall—reaching only as high as the ancient fragment they contain (Fig. 1).[8] Some original fragments have been judged too fragile or too valuable to remain in the temple and have been placed in museums. At the same time, replicas of some of the original material that has been removed to museums have been used in the restoration.[9]

During all periods, ancient builders, excavators, and restorers at Deir el-Bahri have faced a major geological problem: the unstable nature of the rock in the cliffs behind and above the temples (Fig. 2).[10] Weathered limestone falls in chips and chunks. Ancient rockfalls buried the temple ruins under many feet of debris and perhaps thereby helped preserve them. Now that the temples have been cleared, these inevitable rockfalls could do considerable damage.

Wysocki described a terrifying experience that occurred on March 31, 1969, while masons were preparing to work on the West Wall of Hatshepsut's Upper Courtyard. A slight earthquake shook loose nearly 40 tons of rock, which cascaded down about 125 feet onto the Upper Terrace.[11] Fortunately no one was injured and damage to the temple was slight. The Polish mission spent a great deal of time studying this rockfall hazard and considering alternative solutions. Removing loose chunks from the cliff before they could fall would have been expensive, and it still would have been necessary to protect the temple during removal. Methods to anchor loose pieces to the cliff face or cover the cliff face with netting to catch rockfalls were deemed unworkable and unsightly. Instead, the archaeologists discovered the method used by the ancient builders and copied it!

When work began in 1968, only a few remnants of the facing wall above the West Wall of the Upper Courtyard remained intact. Rock debris formed a talus slope above and behind the wall. As the restorers removed this loose material, they discovered that the Esna Shale bedrock of the cliff had been excavated to form a platform or

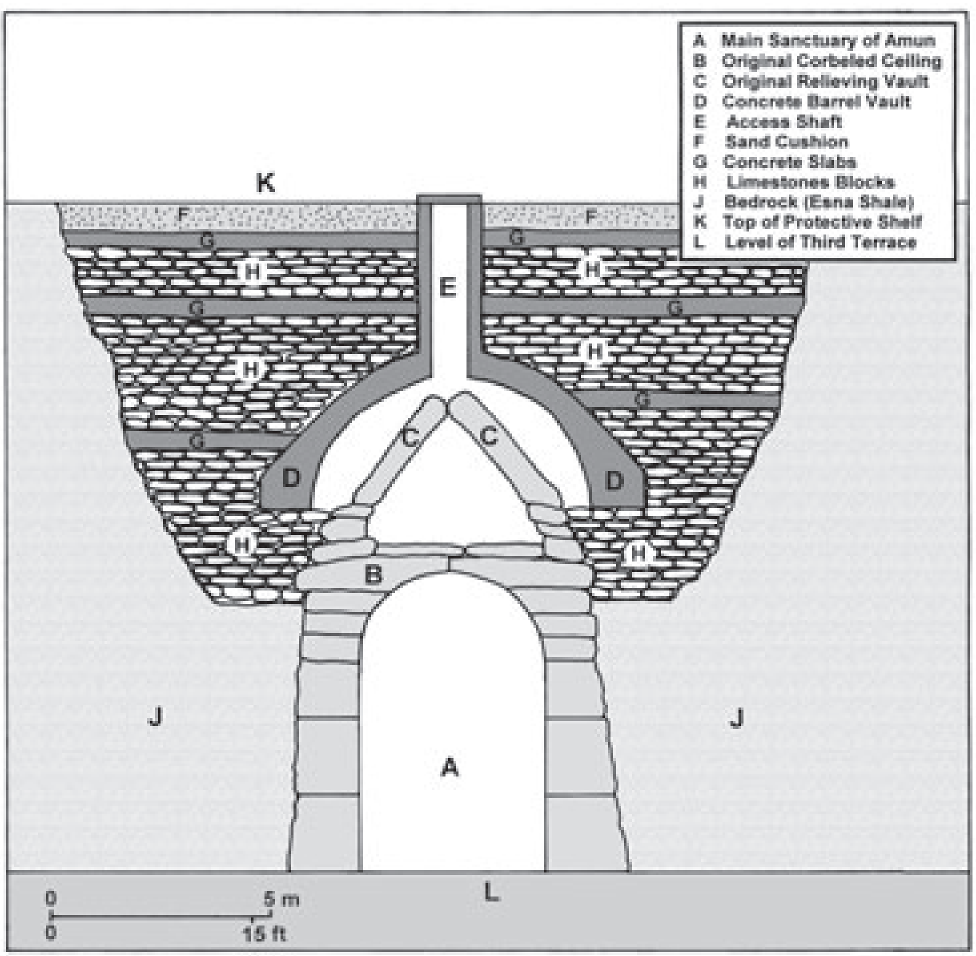

Fig. 3. Cross-section through Amun sanctuary (on Upper Terrace) showing ancient vault and modern reconstruction. (Based on Wysocki 1983.)

"shelf" 46 feet above the top of the West Wall and running the entire length of the temple.[12] The platform was originally 31 feet deep, but the outer (eastern) half had been pulverized by repeated falls of limestone from high on the cliff. The expansion of this shattered shale, when wetted by the infrequent rainstorms, had pushed out the West Wall and toppled the upper facing wall. Once the debris had been cleared back to sound bedrock, it was necessary to fill the gap so that the West Wall and facing wall above it could be rebuilt. The gap was filled with layers of crushed limestone covered with lime mortar. Horizontal, reinforced-concrete pads were placed at intervals in the rising fill to prevent a large falling rock from cracking the fill. Finally, a sand cushion was placed on the top of the rock fill. The platform was completed in 1982, and its effectiveness was demonstrated in 1985 when another avalanche of 50 tons of rock fell harmlessly onto the reconstructed platform from which it was safely removed.[13]

During the work on the platform an additional aspect of the original construction was revealed. The Amun sanctuary, which has the appearance of rock-cut chambers lined with fine limestone slabs, had in fact been built in a trench that was cut into the cliff. This trench extended from the top of the platform to the floor of the Upper Courtyard (Fig. 3, previous page). The sanctuary's first chamber (the high-ceilinged barque chamber) was built of limestone blocks within this trench. Its ceiling was corbeled with more limestone blocks and then cut out from below to give the impression of a curved vault.[14] Above this ceiling, a relieving vault was created by pairs of leaning gable blocks. Then the trench was refilled to the level of the platform. Wysocki found evidence that this was actually a remodeling of Tuthmosis II's original rock-cut sanctuary ordered by Hatshepsut.[15]

The original ceiling blocks and relieving vault blocks were in excellent condition. But to protect them, Wysocki obtained permission from the Egyptian authorities to erect a reinforced-concrete barrel vault above the ancient relieving vault before refilling the trench. A shaft was built to provide access to the interior of the barrel vault from the restored platform above so that the ancient construction can be examined in the future.

The West Wall of the Upper Courtyard was not the only one threatened by disintegration of the Esna Shale formation on which the temple sits. In fact many of the porticos' western walls that had been built directly against the bedrock were affected. Modern excavators found that these walls were either bowed outwards or had buckled and spilled their blocks onto the ground.[16] The only solution was to excavate the shale debris down to sound bedrock. To prevent further disintegration, the shale was then isolated from the atmosphere by a layer of bitumen. The space between the bedrock and the wall was then filled with limestone chunks and mortar. Reinforcing bars were placed into forms to pour concrete vertical backing walls or horizontal pads.[17] Continued surveillance and repairs will be required in the future to combat the geological hazards.

THE VALUE OF RESTORATION

Anyone visiting the restored Hatshepsut Temple will be very impressed by the current state of the monument compared to its condition in the 1800s. But has the goal been simply to create a tourist attraction, a sort of ancient Egyptian Disney World? Absolutely not! Although tourists may be the most numerous beneficiaries, the real value of the restoration has been the new knowledge in a number of fields that will be studied by scholars for years to come.

In fact, restoration requires research and produces data that cannot be achieved by simple excavations, or by the study of fragments in storerooms scattered in museums across the world. Every restoration decision is based on the most meticulous consideration of available architectural and epigraphic evidence. Rebuilding has given architects an appreciation for ancient construction methods including the realization that the Egyptians recognized the dangers inherent in the Deir el-Bahri site. We now have a better understanding of the building phases and which king was probably responsible for each stage. The restored Temple of Hatshepsut can be studied to determine its place in the evolution of temple architecture, noting where archaism was employed and where new features were introduced.

In general, restoration provides better conservation of fragments than leaving them lying in the ruins, especially given the dangers from ground water, rain storms and rockfalls. The storage and conservation of thousands of loose fragments creates a huge burden for monument site managers. Furthermore, viewing reassembled inscriptions in context is more valuable than in a jumble of separate fragments. Reassembled scenes have provided Egyptologists with new information about religious rituals and the events of an important period of Pharaonic history.

Perhaps the most interesting consequence of restoration is the insight it gives us into ancient esthetics. Who can visit this masterpiece without feeling a direct human link with the remarkable woman who inspired it?

ENDNOTES

1. Sampsell 2005. "The Mortuary Temple of Hatshepsut at Deir el-Bahri: The Construction and Restoration of a Masterpiece." *The Ostracon* 16 (2): 13–20.
2. It is impossible in this brief report to acknowledge the dozens of Polish experts who have worked at Deir el-Bahri over the years. Their names are listed in Szafranski 2001.
3. Lipinska 1977, 11.
4. Szafranski 2001, 63.
5. "Vertical" walls built against the natural rock of the cliff actually had batter of 5%, that is, their tops leaned slightly back against the bedrock. A similar batter was seen on outer faces of some of the freestanding walls of the temple. Wysocki (1992a, 242) postulates that all battered walls were built this way to improve their ability to withstand the pressure of the enclosed rubble. Such construction was not required for shorter, thinner walls, and they were vertical.
6. Wysocki 1992b.
7. Karkowski 1990; Kwasnica 2001.
8. Dabrowski (1996) said that in 1960 none of the pillars or Osiride statues of the Upper Portico remained intact. Many fragments of the pillars were found, but they had been viciously damaged and then recut.
9. The best example of this is the block with the picture of the fat Queen of Punt. This block was stolen from the site shortly after it was uncovered. The block was recovered, however, and placed in the Cairo Museum where it remains. A replica is located in the temple.
10. Wysocki 1983; 1992c.
11. Wysocki 1983, 245.
12. Knowing that many aspects of Hatshepsut's temple used Mentuhotep's adjacent temple as a model, Wysocki explored the Mentuhotep temple and discovered it had a similar platform

cut into the cliff above it (Wysocki 1983, 251). Unfortunately the thin layers of shale in the Esna Formation were not strong enough to resist the impacts of the falling chunks of limestone. (Wysocki 1983, 246, 249).

13. Wysocki (1992c, 465). So far the rockfalls have not involved any of the "towers" at the very top edge of the limestone cliff. These weigh thousands of tons, and if one fell, it would surely destroy the temple.
14. Several other chambers at the temple have an apparently-vaulted ceiling cut into a corbeled roof, but they do not have relieving vaults over them. These vaulted ceilings occur in Hatshepsut's offering chapel and the Anubis chapel on the Upper Terrace, and in the Hathor chapel and Anubis chapel on the Middle Terrace.
15. Wysocki 1992a, 243, 5. One piece of evidence is the fact that the north and south walls of the barque chamber are not bonded to its east wall, which still retains an original limestone doorway inside Hatshepsut's granite portal.
16. Baraize 1906; Wysocki 1983, 245; 1984, 347-8; 1992c, 467.
17. Wysocki 1992c.

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A Continuous Thread:

Flax Spinning in Ancient Egypt

Rhonda K. Hageman

Each of the great early civilizations was characterized by its use of a single important fiber for the making of textiles: Mesopotamia was the home of wool, China has been known for its silks for millennia, and Mesoamerica perfected the use of cotton. Dynastic Egypt, for good reason, is known as the "land of linen" (Barber 1994, 185; Wilson 1979, 12). Anyone who has handled mummy linen, or marveled at tomb paintings of sheer linen garments, must have wondered about the process of making this most Egyptian of textiles. It was a complex process, and research has shown that the peculiarly Egyptian approach to linen spinning and weaving is not only different from the classical and medieval European methods of linen production, but also different from linen handspinning as we know it today.

One has to question how it was possible for the people in dynastic Egypt to produce the phenomenal fabrics for which they are known. There is a common claim made about Egyptian textiles: that the ancient Egyptians could weave linen so finely that it cannot be duplicated even by the highest-quality manufacture today. This sounds as if it were a modern myth about the so-called amazing abilities of ancient Egyptians to do what no one now can imagine, but multiple sources attest to the extreme fineness of Egyptian linen. According to an article produced by the National Park Service, the Egyptians "became experts at the creation of linen textiles which cannot be rivaled in strength and fineness of weave today" (Cotton 1996, par. 2). In the entry on mummy linen in *The Encyclopedia of Mummies*, Bob Brier (1998, 117) notes that "the Egyptians were great weavers and some of their linen contained as many as 540 threads to the inch—the finest European linen has approximately 350." Textile historian Kax Wilson (1979, 13) also points out that some Egyptian linen contains over five hundred threads to the inch. Note that this measurement includes both warp (lengthwise) and weft (crosswise) threads in the count, so that the fabric as woven would have had some 200 to 250 warp ends per inch. To understand how this was possible, it is useful to explore the spinning tools and methods used in pharaonic Egypt.

Fig. 1. Old man rippling flax. Young man carrying flax. Modified from Dollinger (2005) who quotes C.R. Lepsius, *Denkmäler aus Aegypten und Aethiopien.* Flax shown in yellow.

Linen thread and fabric are produced from flax, *Linum usitatissimum* ('most useful'), which is a *bast* fiber, meaning that the fibers come from "the inner bark tissue of the source plant" (Amos 2001, 33). The scientific name of this plant indicates not only its usefulness to humanity for millennia, but also the fact that, while the plant and its fiber are called *flax*, the spun thread and the fabric woven from it are referred to as *linen*. The flax stalk has a woody or pithy core, and "between this center and the outer bark are the tough flax fibers—raw linen" (Brier 1998, 117).

Fig. 2. Pottery spinning bowl with molded clay ring. Flax thread and water added digitally (Quirke, 2003).

Flax fibers are more desirable the longer they are, so flax is usually harvested not by cutting but by pulling up the entire plant; in a bundle of flax fibers (called a *strick*), one can see which end is the root end and which is the tip end. The finest flax fiber is harvested by pulling the plants while the stems are still young, supple and green. This finest of fibers would have been used for royal linen. Wilson (1979, 13) notes, "The higher one's place on the social scale, the finer the weave in one's mummy wrappings." Once the flax stalks have been harvested, the laborious process begins of separating the usable fibers from the rest of the plant. As Amos (2001, 167) observes, "It does take a lot of work. Flax passes through several stages of abuse before it becomes a useful textile fiber." After drying the stems, one must *ripple* the flax stems, pulling them through a rough comb-like device to strip the seeds from the stems (Fig. 1).

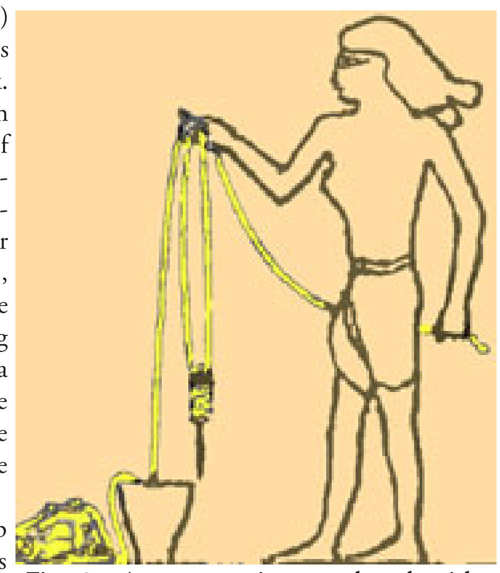

Fig. 3. A woman twists two threads with a high-whorl spindle. Digitally modified from Dollinger (2005). Flax shown in yellow.

The next step in this process is *retting*, a term that is derived from an archaic English

Fig. 4. A Middle Kingdom flax spindle and other textile implements (Field Museum, Chicago, Ill.). Author's photo.

form of the verb *rot* and refers to the rotting of the stalks in moisture to the point that the fibers can be separated from the rest of the stem tissue. Flax fibers can be either *water-retted* by soaking them in water (either in ponds or running streams) until retting is complete, or they can be *dew-retted* by spreading them out on the ground, or a handy rooftop, to be wetted repeatedly by each morning's dew. Egyptian flax workers, having few or no running streams at hand, used artificial pools for flax retting, leaving them in the stagnant water for ten days (Brier 1998, 117). Wetting, either constant or repeated, causes partial rotting of the stem tissue of the plant, so that the tough, strong fibers can be separated from the rest of the plant. Once this has occurred, the stalks are spread out to dry completely.

The next steps in flax preparation after retting are breaking, *scutching*, and *hackling*. The stems have to be broken or crushed, usually by being pounded repeatedly. This crumbles the pith and woody parts of the stalk, leaving the long fibers. The fibers are then scutched, or beaten to remove most of the unwanted plant material from the fibers, and finally hackled, or drawn through several sets

Fig. 5. "Two wooden spindles UC 7306ii, 7809, and a wooden netting needle UC 7806: UC 7306ii (right) are from el-Lahun, probably late Middle Kingdom, 1850–1750 BC, with modern yarn attached, the other two items are from Gurob, New Kingdom, 1550–1069 BC" (Quirke 2003).

of sharp metal teeth of increasing fineness to finish separating the textile fibers from the remaining unwanted plant material. Hackling also separates the long, straight fibers, called *line* flax, from the shorter fibers called *tow.* At this point in the process, "over 85% of the original plant has been removed" in order to get flax fiber into a spinnable form (Cotton 1996, par. 17.) The flax fibers are then ready to be spun into thread, and it is at this point that the Egyptian and European flax spinning practices differ markedly.

European flax spinners practice draft spinning,[1] but Egyptian spinners made linen thread in a two-stage process. In the first stage, the flax fibers were first split lengthwise to the desired degree of fineness and then spliced end-to-end to create long threads or filaments called *roves*. A website article (Quirke 2003) contains photographs of several balls of spliced rove which were found in a Middle Kingdom site at el-Lahun. From examination of these roves, it is evident that the textile workers spliced flax filaments end to end in pairs. A few feet farther on, when one pair of fibers ended, they spliced in a new pair, and so on until the desired quantity of spliced rove was produced. Amos describes how handspinning historian Bette Hochberg determined (from examining a museum piece under high magnification) that "the fiber-processor … had then laboriously made roving by laying three-fiber bundles together, overlapping a new fiber onto the end of each single component as it ran out, and securing the join with a tiny dab of spit, paste, or similar adhesive" (Amos 2001, 103n1). What makes such splicing possible is a unique quality of flax fibers: they contain a considerable amount of pectin, which serves to glue the fibers together when moistened, usually with saliva (Barber 1994, 191; Dollinger 2005, 1). Amos continues, "When this roving was finally twisted to give it strength, the resulting yarn was nowhere thicker than four fibers" (Amos 2001, 103n1). Various tomb illustrations of weaving shops and spinning in progress depict girls preparing the spliced roves by rubbing the moistened fibers over a smooth stone to make the spliced joins stick together (Barber 1994, 191).

Therefore, in the many tomb paintings that appear to show women spinning with a single spindle, the women are in fact not actually spinning but twisting the already-prepared spliced roves into strong smooth thread, which is the second stage of the process. A tool that greatly facilitated this process was the spinning bowl or fiber-wetting bowl, a shallow clay bowl with a vertical clay loop molded into the inside bottom of the bowl (Fig. 2). The strands of flax pass through this loop.[2] As Barber (1991, 73) explains in her *Prehistoric Textiles,* "Before adding twist with a spindle, the women ran the end of the yarn through a looped bowl—the whole ball was put into the bowl if the yarn was in ball form, otherwise only the end was run through and the coil remained on the floor … the primary use had to have been to force the thread through water as it unrolls from the ball or coil of spliced rove."

In Fig. 3, a painting detail from the tomb of Khnem-hotep at Beni Hasan, a young woman twists two threads together with a spindle. One thread emerges from a bowl at her feet, and passes through her hand and down to a hook on the end of a high whorl spindle; the other passes from behind her, over her hand and down to the same hook. The spindle would have been rotated to twist the wet filaments into thread as they passed through the spinner's hands. Occasionally, the spinner would have paused to wind finished thread onto the spindle shaft, start the shaft turning again, and continue.[3]

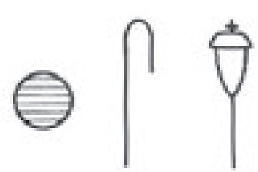

Fig. 6. From Barber (1991, Fig. 2-11).

The form of Egyptian spindles are designed for this method of thread formation. Egyptian spindles for spinning flax invariably have the whorl or weight near the upper end of the spindle shaft as opposed to the lower end (Figs. 3–5). Note that the spindle whorl photographed in Fig. 4 is not shaped in any way; it is simply a thick disk of wood, approximately 2.5 inches in diameter.

This is in contrast to the European or Mesopotamian wool spindles, which generally have the whorl at the lower end of the shaft. In fact, the hieroglyph for the verb 'to spin,' *ḫ-s-f,* shows a high-whorl spindle as the determinative (Fig. 6).

The nature of the fibers being spun is fundamental to understanding the design of the spindles used in different regions. In Europe and Mesopotamia, the chief fiber spun was wool. Wool fibers naturally contain kinks, called *crimp*, in their structure, which enable wool fibers to easily grab onto each other during the spinning process, and each fiber is covered with tiny scales which further interlock with the scales on the other fibers in the thread. Therefore, wool does not need a great deal of twist for strength. Flax, on the other hand, is quite smooth and hard of texture. It does not grab onto itself readily, and therefore needs much more twist per a given length than a wool thread does.

Amos (2001) discusses at some length a study on the properties of low-whorl (European-type) and high-whorl (Egyptian-type) spindles, and in particular their respective rotational speed in revolutions per minute (RPM). A low-whorl spindle must be started by twirling or snapping with the fingers at the top of the spindle shaft, and its top speed averaged approximately 400 RPM given a 3-inch diameter whorl and a 3/8-inch diameter shaft. On the other hand, a high whorl or Egyptian-type spindle is started by rolling the shaft down the spinner's thigh, and the average rotational speed of the same spindle used in this way was 2,050 RPM. Amos (2001, 177–178) notes that this speed was easily achieved with no difficulty by all spinners in the study.[4] It seems clear, therefore, that the different types of spindles used in Europe, the Near East, and Egypt developed in response to the qualities of the particular fibers being spun in those regions. Furthermore, the methods of spinning in those regions also varied in response to the fibers used. Whereas the spinners in dynastic Egypt were adding twist to a lengthy filament that was already prepared before twisting, the spinners in Europe and Mesopotamia were draft-spinning wool, and the amount of twist needed to accomplish this task efficiently is much less than is required to make strong weaving warp out of spliced flax fibers.

Finally, it can be seen that the astonishing fineness of some Egyptian linen can be directly attributed to the uniquely Egyptian methods of creating flax thread, by splicing individual filaments together and then adding twist so as to create thread of a consistent fineness not producible by any sort of draft spinning. This would suggest that the tomb paintings of royalty and nobility in garments of nearly transparent linen are not as exaggerated as one might imagine, and that they are fairly faithful representations of these rare and beautiful fabrics.

ENDNOTES

1. In medieval Europe, and still today, the bundle, or *strick*, of line flax is bound onto a stationary holder called a *distaff*, and the fibers are drawn out by the spinner a few at a time to be fed into and twisted along with other fibers already in the forming thread. The ends of fibers already in the thread overlap and catch onto the ends of the additional fibers, so the mass of fiber is both attenuated and twisted in the same operation. This technique of spinning, by drawing fibers gradually out of a loosely organized mass of fiber, is called *draft spinning.* However, there are no tomb paintings or other representations of Egyptian spinners using distaves, and no paintings of spinners working with stricks of line flax.
2. Barber (1994, 254) also discusses an intriguing point regarding these spinning bowls. She notes that "clay imitations of Egyptian fiber-wetting bowls" suddenly appear in early layers of Late Bronze Age sites in Israel, but not earlier. "The appearance of these humble textile tools, used only by women, alerts us that this is a time when *women* had just arrived in Palestine from Egypt in considerable numbers and settled there—and there is no other such time that we have found. Thus, out of the several points in Egyptian history that scholars have suggested for the date of the Exodus, the women's artifacts tell us that this one (around 1500 to 1450 B.C.) is the archeologically most probable layer to equate with their Exodus from Egypt."
3. This would explain some of the very odd-looking (to modern spinners at least) Egyptian depictions of women spinning: a thread emerges from a bowl or basket, and then goes to her hands and then to a spindle. The women are not spinning the thread, as the continuous thread had already been formed; they are simply adding twist to the pre-existing thread by the turning of the spindle.
4. This author has observed on a number of occasions that, under just the right conditions with the right spindle whorl dimensions and enough speed, one can actually *hear* a top-whorl spindle whirring in the air. Moreover, there are anecdotes of modern high-whorl spindles from certain manufacturers (especially where the whorls are carved in some type of flower shape with petals) that spin fast enough from one brisk roll down the thigh to actually develop lift, like miniature hardwood helicopters: Bernoulli's principle in action. It is impossible to get a low-whorl spindle turning fast enough either to whir or to lift. This is, however, a desired feature, not a problem. No one would want a wool spindle to turn that fast; the amount of twist that would develop would make drafting of loose fibers impossible. It is, however, ideal for inserting lots of twist quickly into a very fine bast yarn.

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Coloring the Ancient Egyptian World

Heather Van Benthem

It is perhaps surprising to the casual observer that the ancient Egyptians used such an enormous amount of color. Temples and tombs were originally covered with colorful paintings. Thousands of years of exposure have stripped away the vestiges of this remarkable art from most outer surfaces, leaving those who wish to study Egyptian painting with what little remains on interior surfaces, papyri, some statues and written records.

In order to achieve uniformity in style and size, artists used guidelines on both interior and exterior walls to make grids for most of the paintings and carvings. These were similar to chalk lines used today, but in ancient Egypt string was dipped in red paint, stretched across a wall and snapped at regular intervals. The secondary artists drew the outlines of figures and glyphs within the grids using red paint, and master artists then corrected the drawings in black paint before the final painting or carving was completed.

Scaffolding was used for higher areas, and lamps provided interior light. These lamps were made of clay and were filled with vegetable oil or animal fat and floating wicks; it is probable that a small amount of salt was added to the oil to produce little or no smoke. Painting implements included water pots, palettes of shells or broken shards and palm fiber or reed brushes.

Colors were mixed with water and adhesive, most likely a form of gelatin glue (size), gum or egg white (albumin) to bind the paint to the surface being painted. Gypsum plaster was usually used on walls, and whiting (chalk) plaster was most often used on wooded objects. A thin layer of varnish was sometimes used over a finished painting, as can be seen most notably in the temple of Seti I at Abydos.

The only colors employed were red, black, white, yellow, green and blue. Creativity seems not to have been a prime directive in color choices, as their usage was symbolic and demonstrative. For example, women were usually depicted in yellow, while men were usually shown in red. Foreigners to Egypt's south were usually depicted in black to distinguish them from Egyptians and other foreigners.

While it is interesting to consider where each color was used, it is even more interesting to examine why each color was chosen. Mankind has made strong and fairly consistent connections with colors since long before the ancient Egyptians created their masterpieces. Could it be, then, that the ancient Egyptians made subconscious decisions in choosing which colors to associate with their painted images, particularly the gods? Was there an innate human directive that drove them to connect with the emotions inherently assigned to color by all of mankind, past and present?

Healing with color in the ancient Egyptian world started with the god, Thoth. "[T]he Ancient Egyptians used colored minerals, stones, crystals, salves, and dyes as remedies, and painted treatment sanctuaries in various shades of color" (Graham 1998, 5). Healing with color has continued and grown over the millennia and is still practiced by those seeking alternative medical solutions today. Many experiments, both accidental and directed, have been done over the centuries to determine the effects of color on the human mind. This interest has also been applied to the study of the paintings of the ancient Egyptians.

Red was one of the most important colors in ancient Egypt and was derived from iron oxides and red ocher. It also was "a pigment used from the earliest prehistoric times" (Redford 2001, s.v. "color symbolism"). Red is associated with feelings of arousal, disturbance, anger, danger and fury. It is an intense color that increases blood pressure and elevates muscle strength. It stimulates the sympathetic part of the autonomic nervous system—the involuntary actions of the nervous system that prepare the body to react to stress or emergency situations. Red spurs the survival instinct of fight or flight. Given that early Man was chiefly concerned with matters of survival, it is logical that his first foray into the world of color would be red. It is a life-giving and protective color, again demonstrating the benefit of adrenaline in a world of survival.

Red is also associated with blood, fire and the sun, each of which has the power to give life and to cause harm. Interestingly, plants grown under red light tend to shoot up faster and taller initially but experience stunted long-term growth. Rodents kept under red light develop larger appetites and growth rates. These are both indications of a live-for-now response, which may be one reason for the short life expectancies of early Man.[1]

In ancient Egypt, the god Set is usually depicted in red. He caused storms and was the personification of evil and the powers of darkness. He represented chaos and threatened order in the world, yet he also protected the sun god each night through the underworld. The sun is the most basic need on Earth, and the world certainly must have seemed more chaotic to the earliest humans; therefore, using the primal color red for Set seems an appropriate choice. Furthermore, people with red hair or skin were thought to be under the power of Set. There is an interesting connection here that is related in the Bible. In the Old Testament story of twin brothers Esau and Jacob (Gen. 25: 24–27), Esau was born covered with red hair; Jacob was not. Esau spent his time out hunting, while Jacob farmed. There seems to be a clear distinction between the association of red with earlier humans (hunter-gatherers) and the softer colors used after the later innovations of agriculture and animal husbandry.

Black was another important color in ancient Egypt. It was derived from carbon, such as soot or charcoal. To the ancient Egyptians, black symbolized death, night and the underworld, which are all regenerative concepts in the Egyptian worldview. It was the color of transformation. Indeed, it was the color of Egypt itself, as it was used to depict the fertility and resurrection that came with the silt left by the inundation of the Nile. The area of Egypt directly alongside the Nile was called black Egypt, and the desert was known as red Egypt.

Osiris, the god of the afterlife, and Anubis, the god of embalming, were often painted black or dark green. Re's name was also often written in black, regardless of the color of the surrounding text. Black is sometimes associated with royalty, in accordance with their renewal and resurrection in the afterlife and their connection with Osiris. As opposed to red, black was considered to be a lucky color. This is interesting as it corresponds to the modern accounting system that shows debts and liabilities in red and credits and assets in black.

White came from calcium carbonate (whiting or chalk) or calcium sulfate (gypsum). White is all colors together, representing the full visible spectrum. Sunlight, directly or indirectly, is required by all life on Earth. Life, including mankind, evolved under this light and requires the full spectrum in order to function properly. To the ancient Egyptians, white signified the verb sense of light, as in the sun "whitened" the Earth in the morning. It was used to denote the moon, as well.

White was also the symbol of purity, omnipotence, the sacred and simple. It was the color associated with priests and their tools and holy ceremonies. Many temple floors were covered in white calcite, popularly referred to as "Egyptian alabaster." White was also employed to depict silver when used in conjunction with gold, depicted in yellow. In addition, "because red and white were opposites in meaning, they were at times placed together to symbolize completeness" (Stratos 2001, 5). Given the qualities associated with each color, this appears to be a joining of good and evil to fully embody the human and divine experience and motivations. On a less ethereal—and more practical—level, white was also the color of most of the clothing shown in paintings.

Yellow was derived from yellow ocher, indigenous to Egypt, and from orpiment, imported from Asia. It is a highly active color, stimulating the nerves and, often, violent reactions. It has been suggested that there might be a correlation between yellow streetlights and violent crime.[2] It is the color linked with intellect, rationality, will, personal power, and the abuse of power. It causes stress disorders and digestive problems.[3]

Perhaps it is its explosive nature that caused yellow to be used by the ancient Egyptian painters as a daytime color and to be connected with hunting, a daytime activity. It also carried solar significance and was linked with the sun and with gold. Yellow represented the eternal and indestructible. The flesh of the gods was said to be have been made of gold. The color yellow bears a close link with Re and the deceased's transformation in the afterlife as the deceased hoped to join the gods in the afterlife.

Green paint was made with powdered malachite, a natural copper ore from the Sinai and Eastern Deserts; or from a frit, an artificial substance used for making glazes and enamels. Green has been used since prehistoric times in association with life. The color symbolized new life, growth, fertility, rebirth, resurrection and vegetation. As mentioned above, the god Osiris was often painted with green skin in reference to his resurrection and power over new vegetation. Green is a healing color, connected with well-being and flourishing health. The Eye of Horus amulet, worn to provide good health and protection, was often green.

To the ancient Egyptians, malachite and turquoise were symbolic of joy and delight. Green turquoise was especially valuable because of its rarity and its importation from Turkey and was connected with Hathor and the sun at dawn. The stone was often used in funerary equipment due to its strong association with the sun's rebirth each day. Coffin faces were painted green to identify them with Osiris and to guarantee rebirth in the afterlife.

Green was also the color of the heart scarab amulet, which was placed in the chest cavity of a mummy to protect the actual heart from any mishap. In an interesting cross-cultural connection, in a Far Eastern belief in a system of seven chakras that run through the body, the heart chakra is considered to be green in color. According to Helen Graham's work (1998), so strong is the connection with the heart that the color green is associated with unconditional love, compassion, forgiveness, understanding, sensitivity and immunity. Along with blue, green stimulates less violent reactions and has positive and beneficial effects on Man.

The final color in the ancient Egyptian palette is blue. Blue was also the last color to be used chronologically, not being added until approximately 2550 BCE. Initially rare, with the passage of time, blue became the most prestigious color. It was derived most commonly from a frit created by heating together silica, a copper compound (usually malachite), calcium carbonate and natron. It also came from the mineral azurite (blue carbonate of copper) and lapis lazuli. Lapis lazuli was imported primarily from Turkey and, along with turquoise, was associated with joy and delight.

Blue is connected with tranquility, well being, calmness and regeneration. It decreases blood pressure and relaxes anxious people. Blue stimulates the parasympathetic part of the autonomic nervous system, which opposes the sympathetic nervous system (stimulated by the color red). Its effect is in slowing the heart rate and causing muscle fibers to smooth, blood vessels to dilate and pupils to contract. Blue is the antithesis of red in that it engenders a reaction of calmness and relaxation. This later-added color and the stability it fosters parallels Man's progression from a survival-based, instinctual existence to a rooted and more secure way of living. This is further evidenced by plant and rodent studies. Plants grown under blue light grow more slowly at first but ultimately become tall and thick. Rodents under blue light grow denser coats. Both of these studies indicate a surety of a longer lifespan and the luxury of more time to expect and prepare for the future.[4]

In the ancient Egyptian world, blue was the color of heaven, the night sky, water and the primeval flood, out of which the sun was born each day. These were somewhat more advanced beliefs, developed when survival was no longer the primary goal and time could be dedicated to the study of the universe, both physical and within Man's mind and belief system. The god Amun-Re, the creator god from the primordial waters, is painted blue. Pharaohs associated with him were shown with blue faces (Stratos 2001, 4). The gods usually had hair of lapis lazuli, and "the rising sun was sometimes called the 'child of lapis lazuli'" (Redford 2001, s.v. "color symbolism"). In ancient Egyptian belief, the god Horus destroyed all evil and was depicted as a hawk with a blue torso (Douma 2001). This is further demonstration of blue's association with calmer, more serene times. Blue, along with yellow, was a divine color and was used in the headdresses of kings.

As evidenced by the analyses, the colors red and blue have received the most attention in studies. This is possibly due to the fact that they are on the opposite ends of the visible color spectrum and cause opposite reactions in many living things. It is also clear that life requires the full spectrum of colors in order to achieve balance and full functionality. The ancient Egyptians must have felt that need, and they left behind mammoth amounts of work for their descendants. It is the good fortune of the student of ancient Egypt that much of that work has survived.

The clichés associated with colors—seeing red, being green with envy, being yellow-bellied, looking blue—haven't come along by happenstance. They are products of a shared reality that has stretched across chronological and cultural boundaries to deeply instill in all of mankind a common system of color analysis. The study of color and Man's connection to it is fascinating and is rendered all the more so when held against the backdrop of ancient Egyptian art. Perhaps it is the inherent anthropologist within all of us that is comforted and excited by the concept that something as mundane and benign as color can be shared with people from thousands of years ago. It is the majesty of Man to be able to pass along something of himself to the next generation. It is his triumph to hold that line and look back to see how far it goes.

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ENDNOTES

1. The author has made use of the data from Dr. John Ott (1973) on the reactions of the plants and rodents to red and blue light; on the other data about the effect each color has on the human body; and on commonly accepted anthropological evidence about Man's evolution to arrive at logical conclusions regarding each color's placement in the development of Man. The reasoned inferences are those of the author and are not, as such, spelled out in the references.
2. In *Discover Color Therapy*, Helen Graham (1998) touches on the work of Theo Gimbel, who suggested the correlation. Gimbel started the Hygeia Studios and College of Color Therapy in Britain and was interested in the link between color and behavioral/physical imbalances.
3. Please reference Graham (1998) for further references to the work of other scientists throughout history and a more thorough discussion of the physical and psychological effects of color.
4. Please see note 1.

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House of Scrolls

Desert Queen by Janet Wallach,

1996, 377 pages. Nan A. Talese/Doubleday.
ISBN 0-385-47408-3.

If Lawrence of Arabia was the brawn behind much of the modern geo-political map of the Near East, Gertrude of Arabia was the brain. *Desert Queen: The Extraordinary Life of Gertrude Bell: Adventurer, Adviser to Kings, Ally of Lawrence of Arabia* is a well-researched, fascinating and easily readable biography of this remarkable woman.

In the late 1800s, an upper-class young English lady had only three "social seasons" in which to find a husband. Gertrude Bell failed. Perhaps it was her plain looks or the fact that she was one of the first female graduates of Oxford that scared men off. Perhaps it was her sharp tongue or her superior intellect. Whatever the reason, her status as a childless spinster haunted Gertrude for the rest of her life. But it also led her to an unconventional life that changed the course of history.

Supported lovingly by a wealthy, aristocratic family, Gertrude took her loneliness to the deserts of the Near East, particularly to Mesopotamia (now Iraq), with which she fell in love. She was a prolific writer. Her popular books and governmental reports, and the hundreds of letters she sent home to family, friends and politicians form the backbone of Wallach's definitive biography.

To call Bell unconventional is a gross understatement. But, as a Victorian gentlewoman, she was also very conventional. She slept alone on desert sands and endured imprisonment by tribal sheiks. Yet even in the most remote stretches of the Arabian Desert, she dined on fine china, drank imported wine from crystal glasses and wore imported furs. Throughout the cities of the Near East, she charmed diplomats in her fashionable French gowns at foreign embassy balls, but welcomed Bedouin murderers and thieves to her desert campsites. She considered herself equal to any man but, back in England, she fought vehemently against voting rights for women.

Bell spent her life among powerful men. She entertained and was entertained by desert sheiks, often the only woman allowed to be unveiled in their presence. She sought their knowledge but was conceited about her superior intellect and experience compared to the top English politicians, with whom she corresponded regularly.

An equal among men, she had the strong passions of a woman. An underlying theme of Wallach's biography is Bell's passion for men she could not possess. She met T.E. Lawrence for the first time at the archaeological site of Carchemish, near Damascus, in 1910. She was forty-two, he was twenty-three; she was already attending classes at Oxford when he was born. Did they have an affair? You'll have to read the book. Wallach is circumspect with regard to the details of Gertrude's most intimate relationships, but her love of several men dominated much of Bell's life.

Gertrude Bell was an amateur but talented archaeologist. She discovered and excavated archaeological sites, and established the world-renowned Iraqi Museum in Baghdad, now even more famous for its looting in the wake of the U.S. invasion of Iraq.

In the early 1900s, Bell knew more about the Near East than almost any other European. She knew and understood the two most powerful desert sheiks: Ibn Rashid, a ruthless ally of the Turks and Germans; and Ibn Saud, the leader of the Saudi tribe, who favored the Western nations. But, as a woman, Gertrude was constrained by the English government before they grudgingly acknowledged her expertise and allowed her to return to the Near East as an employee and informant.

At the outbreak of World War I, the Near East consisted of only four countries or territories: Syria, Mesopotamia, Palestine and Arabia, almost all of which were controlled from Constantinople (now Istanbul) by the Turks of the Ottoman Empire. At the end of the War, Gertrude was instrumental in redrawing the modern borders of those countries.

Wallach's book is not only a biography, it's a history of the Near East, both ancient and modern, doled out in short chapters with even shorter sub-chapters. Almost without realizing it, the reader begins to understand the dynamics of the region and the forces that created the current political situation. The book is an engaging, behind-the-scenes look at the making of the modern Near East, told from a very personal perspective.

Written before the outbreak of the current war in Iraq, *Desert Queen* still provides sharp insights into the forces that created and still control the political picture of the modern Near East. The conflicts between the Sunni and Shiite Muslims play an important role in the story, as do the now-familiar cities of Baghdad, Mosul, Basrah, Karbala, Nasariya, Najaf and other centers of the current conflict. When Wallach was writing her biography in 1996, she could have had no idea how prophetic Gertrude Bell's descriptions of Iraq's problems would be to us today.

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