BRIDGEWATER STATE UNIVERSITY

Bridgewater Review

Volume 24 | Issue 2 Article 6

Dec-2005

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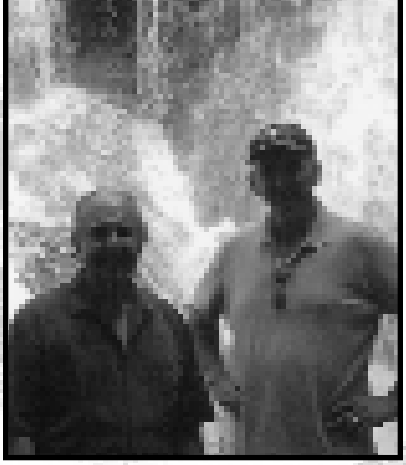
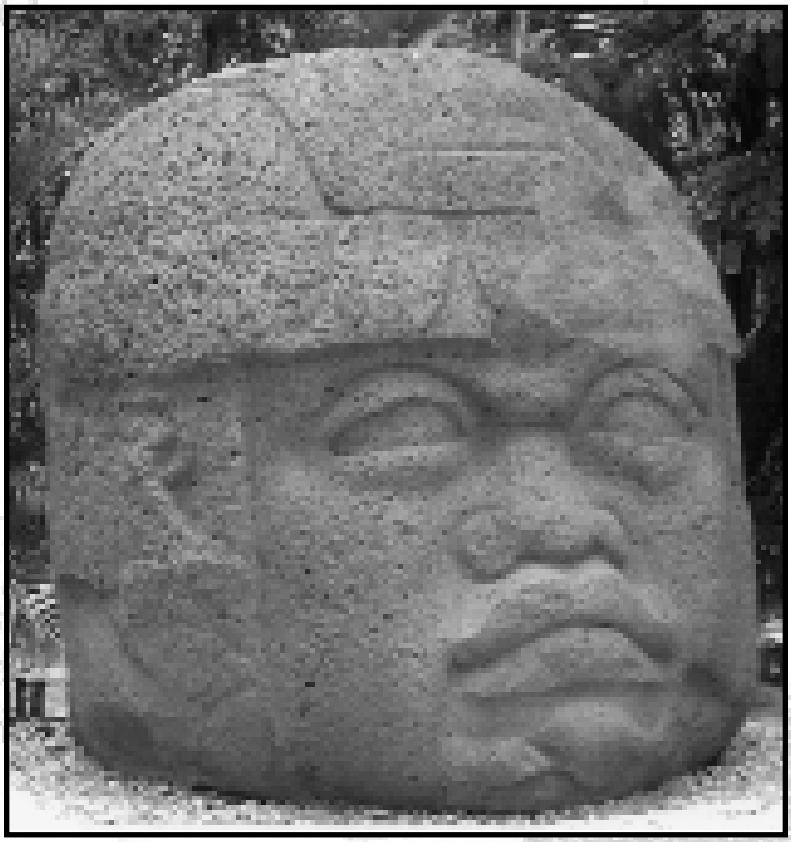


A Mathematical Journey through the Land of the Maya

by Philip Scalisi and Paul Fairbanks
(all photographs by Philip Scalisi)

The MAA's (Mathematical Association of America) Third Annual Mathematical Study Tour took place between May 23rd and June 2nd, 2005. It was the first joint MAA-MEC (Maya Exploration Center) venture. The purpose was to study ancient Mayan mathematics in the Yucatán Peninsula of Mexico. Twenty eight MAA members, ourselves included, traveled through four Mexican states: Yucatán, Campeche, Chiapas, and Tabasco. Guiding us and sharing their immense expertise were three renowned MEC archaeologists: Alonso Mendez, Alfonso Morales, and Christopher Powell. One thing we'd like you to keep in mind as we describe this fascinating journey: the temperature was consistently above 110 F with high humidity. However our guides were so knowledgeable and the structures so fascinating that we were able to concentrate—generally.



THE TOUR

The tour began in Mérida, capital of Yucatán state. There we attended seminars on the ancient Mayan numeration system, geometry, calendrics, and archaeoastronomy. The next day was spent entirely at Chichén Itza, probably the most famous of all Mayan cities. Chichén extends over an area of 32 square kilometers containing structures exhibiting a number of diverse architectural styles: Puuc, Chenes, and Maya-Yucateco. Many buildings also show the influence of the Toltecs and Teotihuacános from central Mexico. Most conspicuous of these is the great pyramid El Castillo, also known as the Pyramid of Kukulcán. It is 24 meters (78 feet) high with a 60 meter (196 feet) wide platform at the base. This was the first opportunity for our 28 mathematicians to scamper up a Mayan structure; the steps are much steeper than we're accustomed to in modern stairways, and the stones used are often loose and slippery. Quite a challenge and quite a sight! The pyramid's nine tiers represent the symbolic number of the Mayan underworld. Stairs on all four sides lead to the temple at its peak. The north staircase is lined on either side with carvings of plumed serpents leading down to giant serpent heads at the bottom. On the spring and autumn equinoxes (March 21st and September 21st), a play of light and shadow by the afternoon sun (around 4:00 PM) causes an image of a serpent "coming alive," descending to its head in March and ascending from its head in September. This is an extraordinary example of the combination of Mayan architectural, astronomical, and mathematical skills. Chichén's plumed serpent is associated with the god-king Kukulcán, the Yucatecan equivalent of the Teotihuacáno god Quetzalcoatl, who was introduced from Central Mexico c. 900 A.D. Kukulcán remained as a major Yucatecan cult until the Spanish conquest around 1530 A.D.

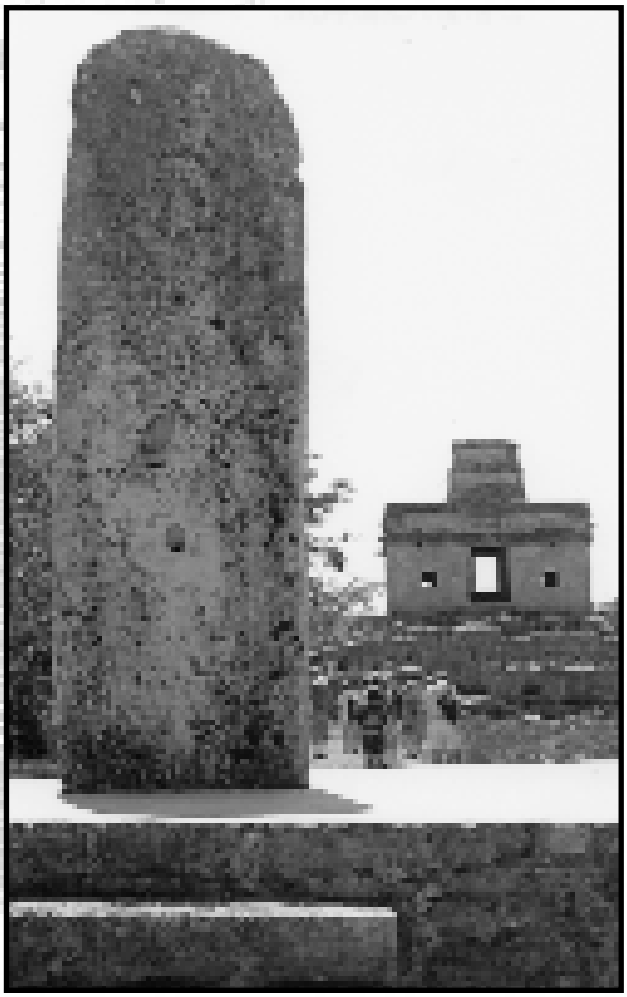
Several of us were fortunate to enter the interior of El Castillo as a smaller pyramid exists inside it! After ascending 62 narrow slippery stairs in a steamy, dark and dank atmosphere, we came upon the chamber of the Chac-mool, a reclining figure with its head looking sideways. Its posture represents a figure descending into the underworld. Beyond this statue is the throne of the Red Jaguar, a painted altar inlaid with jade, bone, and mirrors. This was a memorable experience.

Another important structure at Chichén Itza is the Caracol (the Snail) or Observatory. It was designed for tracking the movements of the moon and planets. Initially built c. 800 A.D., it was altered and added on to over many centuries. The Caracol tower's interior is often described as a spiral, but in reality, it is a series of concentric circles. The inner core consists of a spiral staircase (hence the "snail") which leads to the upper level. There are three window slits in the sides. One points due South, a second towards the setting of the moon at the spring equinox (March 21st), and the third points to the west towards the setting of the sun on both equinoxes and the summer solstice (June 21st).

Chichén Itza contains the Great Ball Court which is the largest in Mesoamerica (168 meters [550 feet] long and 70 meters [230 feet] wide). In addition, Chichén boasts of having perhaps the most spectacular natural phenomenon in the Yucatán, the Sacred Cenote. This natural sinkhole containing water was used primarily for sacred ceremonies, and it was here that Mayan priests cast children, young virgins, and jewel laden warriors in order to appease the rain god Chaac. The appeal of the Cenote to the Mayans may have been partly due to the geographic phenomenon that there are no above ground rivers or lakes throughout the Yucatán Peninsula.

The next day our group journeyed to Dzibilchaltún, a city noted for having one of the longest histories of unbroken occupation of any Mayan site, from c. 500 B.C. to c. 1500 A.D. The most important structure here is the Temple of the Seven Dolls, named after seven crudely modeled figurines found in it. At dawn on the spring and autumn equinoxes, the rising sun beams directly though the east and west doors of the Temple and along the line of the Sacbé, the main path connecting the two centers of Dzibilchaltún. The equinoxes were of great importance to the Mayans as they were indicators for the change in seasons used in their agricultural cycles. This intricate filtering of light into the inner chambers at specified times enhanced the glory and "godliness" of the emperors. Later that afternoon we returned to Mérida for a seminar on Mayan calendrical calculations using the Mayan modified vigesimal (base 20) numeration system. We shall give more details on these topics later.

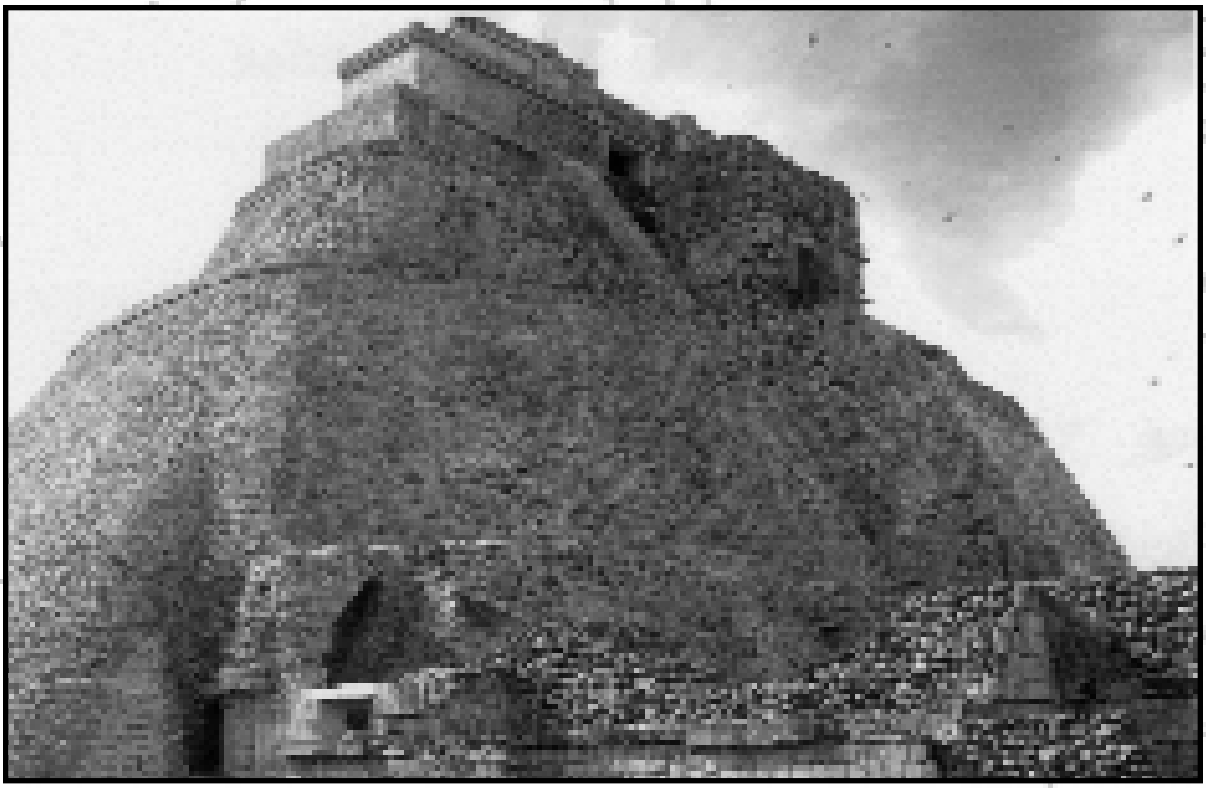
The following day was spent visiting the ruins at Mayapán, the Spanish missionary monastery at Maní, and the caves of Loltún. Mayapán was the last Mayan capital of the Yucatán, rising to prominence between 1200 and 1440 A.D. It imitated Chichén Itza by building smaller but cruder versions of Chichén's El Castillo and Caracol. Our group visited the various structures at Mayapán to take measurements that verified some of the geometric formulas discovered by Christopher Powell. We were also able to meet with various site staff archaeologists and witness new excavations and restorations.



Far Left, Top, Scalisi and Fairbanks at Golondrinas Falls.

Far Left, Center, Olmec Head.

Left, Altar and Temple of the Seven Dolls.



We then journeyed to Maní, where the oldest of all the Spanish missionary monasteries in the Yucatán is situated. It was built c. 1550 A.D. Father Diego de Landa (1524–79) was the first head of the Franciscans and the second Bishop of Yucatán. Landa has become both famous and infamous in Mayan history and archaeology. In 1566 he wrote a book entitled "Relación de las Cosas de Yucatán" ("Relation of the Affairs of the Yucatán"), a thorough account of all aspects of pre-conquest Mayan civilization. Much of our present day knowledge of the Mayan calendars and the decipherment of Mayan glyphs is based on the Relación. But Landa learned in 1562 that a large number of Maya were secretly "practicing idolatry" and so he organized an "auto-da-fé" in front of the monastery at Maní. There the "idolaters" were tortured and humiliated, Mayan ceramics and sculptures were destroyed, and thousands of books ("codices") were burned. Landa had written "the people also used certain characters or letters with which they wrote in their books their ancient things and sciences, and with these figures and some signs, they understood and taught. We discovered a great number of these books with these letters and as they had nothing that did not contain superstition and lies of the devil, we burned all of them with the great lament and despite the Indians." Today there are only four Mayan manuscript codices in existence.

Traveling from Maní, we arrived at Loltún, where the most spectacular of the Yucatán cave systems is located. These caves were occupied by local people from prehistoric times to the mid 19th century. Artifacts dating back to 10,000 B.C. have been found here providing the earliest evidence of human occupation in the Yucatán. The caverns are truly impressive, exhibiting rich rock patterns, sonorous stalactites, and beautiful Mayan carvings from the classic period.

Later that evening we arrived at Uxmal in preparation for a lecture on Mayan calculations on the transit of Venus as seen in the Dresden Codex. The following day was spent taking measurements of the main structures in Uxmal and the nearby ruins at Kabah and Labna. Alfonso Mendez discussed the astronomical significance of the various orientations exhibited by some of the temples, especially of the Pyramid of the Dwarf Magician at Uxmal, the Codz-Poop ("Palace of Masks") at Kabah, and the Great Arch at Labna.

Our next stop was at Edzná in Campeche. Edzná is famous for its unique combination of architectural styles as exemplified by the Edificio de los Cinco Pisos (Building of the Five Stories) built between 652 and 800. In typical Mayan fashion, many of the other structures at Edzná are aligned with the Cinco Pisos along the line of the moon at specific times during the year.

Upon leaving Edzná, we traveled to Palenque in Chiapas. Palenque is considered to be one of the most beautiful and most important of all classic period

Mayan cities. It contains the Temple of the Inscriptions, which sits atop a nine stepped pyramid. The name is from the three panels bearing glyphic inscriptions that were set into the walls of the upper temple. Inside the pyramid is the burial crypt of Palenque's greatest ruler, Pakal II who reigned from 615 to 683. It was discovered in 1952 by archaeologist Alberto Lhuillier after he had come upon a hidden stairway that descended from the upper temple into the funerary crypt. This is closed to the general public, but our guide Alfonso Morales was able to get our party inside to see Pakal's tomb. Another unforgettable experience!

A side trip was taken to the ruins of Bonampak. In one temple, there are the only nearly complete and well preserved mural paintings found in the entire Mayan world. These murals cover three adjacent rooms from top to bottom. They tell the story of Lord Chan-Muann (reigned 776–795) and his battles against the enemies of Bonampak. These paintings are extremely vivid and truly spectacular!

Back in Palenque, several informal sessions were held discussing Palenque's role in Mayan astronomy as well as calendrical calculations using the modified vigesimal numeration system with its related glyphs. We then journeyed to our tour's final destination Villahermosa in Tabasco. There we visited the Parque La Venta, where over 30 colossal basalt heads and other sculptures are on display. These magnificent treasures came from the Olmec site at La Venta and date from 900 to 400 B.C. They were transported to Villahermosa in the 1950s for protection when oil explorations threatened their preservation.

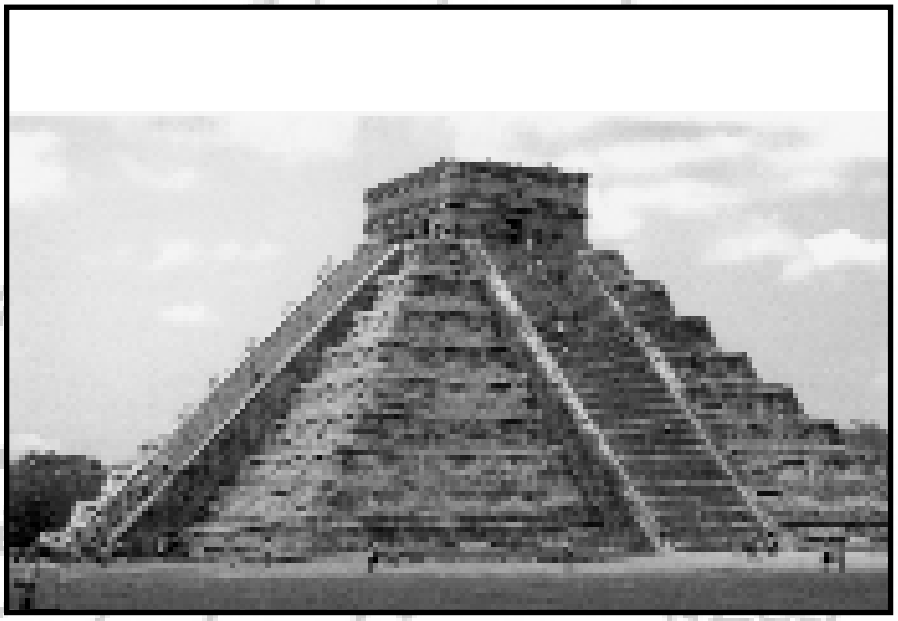
THE MAYAN CODICES

The Maya created an incalculable number of books or codices. They were made of paper made from the inner bark of fig trees, today called amatl (amate) paper. Occasionally, deer skin or cotton cloth was used. They were flattened, colored with a lime paste and then folded accordion style. Today only four codices have survived. This is due mainly to the mass burning of all codices found by 16th century Spanish missionaries. The instigator of this act was Friar Diego de Landa alluded to earlier. Every codex was designed in relation to the spiritual world and dealt with Mayan history, divinations, religion, astronomy and agricultural cycles. Much of our current knowledge of the Maya is based on these codices.

Far Left,
Pyramid of the Dwarf Magician.

Immediately Below,
Temple of the Inscriptions.

Bottom,
El Castillo.



The four known codices are referred to as the Dresden, Paris, Madrid, and Grolier. The Dresden Codex is considered to be the best preserved, most beautiful and complete of the four. It is kept in the Staatarchiv of Dresden in Germany. It is made of amatl paper, and screen-folded into 39 sheets, each 9CM wide by 20.4CM high and 3.5M long when opened. Made between 1000 and 1200, it is linked to the Yucatecan Maya at Chichén Itza. It is essentially an astronomy text which includes tables dealing with eclipses and the planet Venus.

The Paris Codex (Codex Peresianus) is preserved in the Bibliotheque Nationale and consists of 11 sheets, each 13CM by 24CM. Unfortunately it is in poor condition with only the central part of each page reasonably intact. It deals with ceremonial practices and predictions concerning the New Year and the Zodiac. It is thought to have come from 13th centrury Palenque.

The Madrid Codex is preserved in the Museo del Americas in Madrid, Spain. It is screen-folded into 56 leaves, each 12CM by 24CM and dates to the 14th century. It is also known as the Tro-Cortesianus Codex because its first documented owner was a paleography professor, Juan de Tro y Ortolano, and because Madrid's Archaeological Museum felt it belonged to Hernán Cortes.

The fourth Codex is called the Grolier because of where it was originally exhibited (the Grolier Club in New York City). Its current location is unknown. It is also quite unlike the other three in its textual arrangement, and as a result, some scholars feel it is a fake. However, most deem it to be genuine.

—Philip Scalisi and Paul Fairbanks
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Top,
The Caracol (Observatory).

Center,
The Codz-Poop.

Bottom,
MAA Group in the Caves.

MAYAN MATHEMATICS

The Mayans used a vigesimal (base 20) numeration system. The use of base 20 was probably due to their ancient ancestors counting with both fingers and toes. As such, 20 digits, 0 to 19 were needed. Only three special symbols were used to generate them: a dot (•) to represent 1, a bar (—) to represent 5, and a glyphic symbol (⊖) with several variants to represent 0. Numbers were generally written vertically with increasing powers of 20 from bottom to top. For example, 20 and 67 were written  = 1 x 20 + 0 and  = 3 x 20 + 7, respectively. The Mayans modified their system for three or more digit numerals. So, instead of 1, 20, $20^2 = 400$, $20^3 = 8000$, $20^4 = 160{,}000$, etc…, they used 1, 20, 18 x 20 = 360, 18 x 20^2 = 7200, 18 x 20^3 = 144,000, etc…. Thus  = 1 x 360 + 5 x 20 + 3 = 463.

This modified vigesimal system was used exclusively in the codices (especially the Dresden), their monumental stelae, murals, ceramics, and temple facades. It met the needs of astronomical observation and the reckoning of time. The Mayans not only recorded where an event took place, but also when. It was the property of the rulers and astronomer priests, and so its main applications were for astronomical and calendrical calculations.

The Maya used two calendars simultaneously: The Tzolk'in (sacred, ritual) and the Haab (vague, civil, solar). The Tzolk'in consists of 260 days made up of thirteen 20 day months. (13 x 20 = 260). One of the theories for the basis of the Tzolk'in cycle is that the human gestation cycle averages 260 days. The Haab is more similar to our own Gregorian calendar. It is called the "vague" year because it consists of 365 days and does not include a leap year. It consists of eighteen 20 day months. Since 18 x 20 = 360, an extra "month" (the Uayeb) of five days was added at the end of the final full month. The Maya combined the Tzolk'in and the Haab to create a larger 52 year cycle called the Calendar Round. This is because the least common multiple of 260 and 365 is 18,980 days = 52 Haab years = 73 Tzolk'in years.

Also, the Maya measured time on an absolute timescale based on a creation ("starting") date and measuring forward from this. This date is usually taken to be Aug. 13, 3114 B.C. (much like the way we use Jan. 1, 0 A.D.). This linear day count is called the "Long Count." For example, the Leyden Plate/Pendant (Rijksmuseum voor VolkenKunde, Leyden, Holland) shows a Mayan warrior trampling a prisoner on one side and a long count date on the other side. This date is 8 x 144,000 + 14 x 7,200 + 3 x 360 + 1 x 20 + 12 = 1,253,912 days. A simple calculation shows that this pendant was carved in 320 A.D. We abbreviate the form of this numeral as 8.14.3.1.12. It was long believed that the Leyden Plate was the oldest dated Mayan artifact, but an artifact was recently discovered at El Baul, Guatemala which dates to 36 A.D. It should also be mentioned that unlike our calendar, the Mayans had an end date. Dec. 23, 2012. This represents the end of a cycle 13.0.0.0.0.

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