

ARCHAEOLOGY

Building Without Metal Tools

Solution to the long-puzzling problem of how Mexico's prehistoric temples were erected without modern stone-cutting tools is that the ancients turned nature to their advantage.

By MARJORIE VAN DE WATER

► IT HAS LONG been a source of wonder to scientists how the ancient peoples of Middle America could have erected their monumental, elaborately ornamented temples without metal stone-cutting tools or modern means for transporting the huge stones and putting them in place.

Now an engineer, J. Ogden Outwater Jr. of the University of Vermont, has made a study of three such engineering feats, revealing the "versatility and imagination of the builders." The ancients took advantage of the peculiar qualities of the stone with which they worked. They adapted their construction methods to these qualities and applied the forces of nature that were available.

The three monuments studied by Mr. Outwater were examples of three contrasting techniques. One was carved out of the solid rock on the side of a mountain. Another was constructed of huge boulders, carefully finished and fitted and was ornamented with carved reliefs in perfect symmetry. The stone of this monument was hard and dense. The third monument was made of stone mosaic consisting of about 300,000 pieces of thin, flat stone and about 100,000 larger stones.

Natural Stone-Cutting Tool

Water was the natural stone-cutting tool taken advantage of by the builders of the monolithic temple of Malinalco, hewn out of a mountain in the State of Mexico. Mr. Outwater estimates that more than a thousand metric tons of rock were cut away and delicately removed to leave the main temple chamber, decorative statues and staircases and part of another building.

The debris and smaller stones were used to build other parts of the monument.

This monument is located well up the side of the mountain and is accessible only by one narrow trail. That single trail must have accommodated all the workers and all their supplies.

The reason for selecting such a hard-to-reach location for a temple, Mr. Outwater believes, lies in the peculiar qualities of the solid shelf of rock on this mountain and in the fact that a spring of water was flowing directly above it.

This rock, which is volcanic ash containing clay, has the property of absorbing a large quantity of water and of becoming dramatically soft and easily crumbled when it is wet. Yet when it dries out it is quite hard and durable.

Search of the temple site showed the ancients had dug channels from the spring

to the various parts of the building, leading the water where they wanted to work on the stone and holding the water there until it could thoroughly permeate the stone.

This stone becomes so soft when soaked that it is reasonable to suppose the ancients could have used stone or wood mattocks to hack out the stone in the first attack on the construction.

Actually, marks of this type of instrument can be found in the channels leading from the spring.

Since the construction had a very beautiful finish, however, it is obvious that as the work progressed more refined tools must have been necessary.

A pile of what may have been the actual tools used by the builders was found near the site. They were cylindrical stones that have been described as about the size of a rolling pin and sharpened, or tapered, at one end. Mexican archaeologists call them "nails" and have guessed they were used like studs for ornamentation in the finished plastered walls.

They may have served to ornament the temple, Mr. Outwater agrees, but he believes their primary purpose was to finish the stone in the monument.

About three-fourths of the stones were of volcanic lava, the sharp edge of which would readily cut and smooth the soaked

stone. The rest of the stones were of compacted silt composed of clay, lava particles and sand. The particles of lava protrude from them and would have made a good abrasive against the rock.

Ten Years to Build

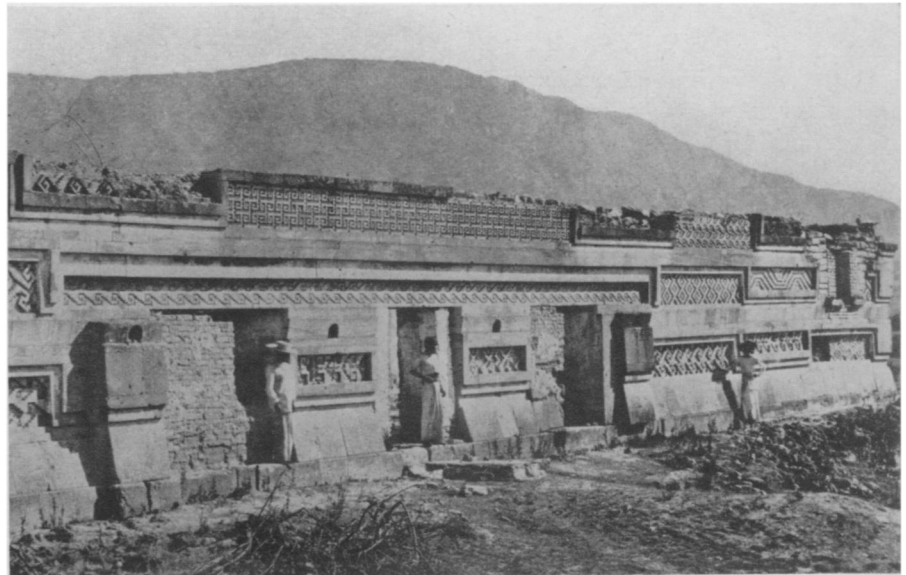
Using a combination of the rough mattocks and lava fine tools, Mr. Outwater estimates that it would have taken about one man-hour to remove 750 cubic centimeters of stone. Then, assuming a 10-hour working day and a 300-day working year, he arrived at an estimate of 400 man-years to build the monument of Malinalco, not counting the time needed for painting, tool-making and other extras.

The maximum number of men who could have worked on the mountain shelf without getting in each other's way was probably not more than 50.

So that the building of the great Malinalco monument must have taken a period of about ten years.

Once the cutting of the stone was completed, it would have been necessary to divert the water so that the stone could harden before the elaborate carving was ruined. This was done. Small dams, which are still in place, were installed to make the water flow around the cliff edge and fall into the valley well clear of the work.

All this complicated technique of using water softening as a means for cutting a temple out of a mountain side and then carrying the water away again was developed for only one single use. In no other place in Mexico has this peculiar type of



ANCIENT INGENUITY—The beautiful mosaic on this ancient temple at *Mitla*, Mexico, consists of about 300,000 thin, flat stones, although the stone used does not lend itself to splitting as slate does. An American engineer believes the ancients may have softened the rock by soaking it in some unknown chemical until it could be split. This photograph of *Mitla* is the property of Dr. G. F. Ekholm of the American Museum of Natural History.

rock been found adjacent to a spring. In no other place did Mr. Outwater see such a monumental temple cut from the live rock of a mountainside.

The prehistoric people seem to have developed the technique in order to take advantage of the unique conditions.

An entirely different technique was used to build the Temple of Xochicalco. The stone of this pyramid is very hard and dense.

The outstanding feature of the pyramid is the symmetry not only of the building but of the carvings on it. It seemed reasonable to suppose that the stones for all four corners and sides were all cut and carved to exactly the same size and shape.

A careful survey of the blocks around the base of the pyramid indicated, however, that this was definitely not the case. Not only was there very little correspondence in size between similarly situated blocks, but the number of stones along each side was different.

Mr. Outwater believes that the pyramid must have been constructed starting at one corner and mating each new stone with the last one already in place.

He estimates that the temple originally must have consisted of about 1,200 carefully finished and fitted stones.

What technique was used for finishing this hard, resistant stone? After experimenting with various methods possible without the use of modern tools, Mr. Outwater believes he has discovered the technique actually used in the prehistoric construction. He found that when two of these stones are rubbed and tapped together dry, the surfaces break off and leave a pock-marked surface similar to that found on the pyramid. This surface can then be pounded until it is flat and smooth.

This was, of course, a time-consuming process. It would have taken a crew of 200 men five years just to finish the stone.

The intricate carving would have been exceedingly tedious but might have been accomplished by the same sort of method.

Third Construction Method

The third temple studied, at Mitla in Oaxaca, was of a completely different construction from the other two. The Mitla temple is ornamented with a beautiful mosaic made of about 300,000 thin, flat pieces of stone, like tiles. In addition there were about 100,000 larger stones in the building, some of which were tremendous boulders in the form of pillars or lintels.

The stone used is a trachyte which stands weather well. It can be easily chipped with flint tools, but does not lend itself to being split like slate.

The secret of how the ancients made this stone into the thin pieces for the mosaic may have been solved by Mr. Outwater.

What he feels is probably an important clue is a big stone cauldron more than four feet in diameter carved out of a boulder and completely immovable. The cauldron was found located near a quarry which must have been a major source of the Mitla stone.

Mr. Outwater reasons that the ancients must have dipped their stone into a soften-

ing agent, let it soak there until it was soft and then cut it to size, using a nearby stream to carry off the waste.

He has as yet no idea what softening agent they used although he has experimented with such common chemicals as

vinegar, potash and urine. He is continuing the search for a suitable chemical available to the ancient Mexicans.

The investigation is reported in *American Antiquity*.

Science News Letter, September 14, 1957

SEND FOR
Free Record

START SPEAKING
FRENCH
OR
SPANISH ALMOST OVERNIGHT!

HERE'S the easiest way to learn FRENCH, SPANISH, Russian, German, Italian, Japanese or Brazilian. Listen to FREE 2-sided non-breakable record. Let your eyes follow words in FREE sample lesson. Almost at once you'll be chatting in a new language with a perfect accent! That's all you hear! No dull, tedious work. Just listen—imitate! It's that easy! Offer may end soon. Rush 25¢ to help cover cost of special packaging, shipping. State language you want. We'll also send free information on full Cortina course. No obligation. **CORTINA ACADEMY**, Dept. 609, 136 W. 52nd St., New York 19.

MAKE MONEY WRITING

.. short paragraphs!

You don't have to be a trained author to make money writing. Hundreds now making money every day on short paragraphs. I tell you what to write, where and how to sell; and supply big list of editors who buy from beginners. Lots of small checks in a hurry bring cash that adds up quickly. No tedious study. Write to sell, right away. Send for free facts. **BENSON BARRETT**, Dept. 163-H, 7464 N. Clark St., Chicago 26, Ill.

TESTA MICROSCOPES

A DISTINGUISHED LINE OF LOW COST MICROSCOPES

LABORATORY SIZE, WITH LARGE, PROFESSIONAL INCLINING STANDS, PRECISE INTERCHANGEABLE OPTICS SIMPLE TO OPERATE AND MAINTAIN INSTRUCTION MANUAL FURNISHED AMERICAN MADE PROMPT DELIVERIES

MODEL F — 100 to 700X \$99.50
Parfocal triple nosepiece. Condenser stage with aris diaphragm. Coarse and fine adjustment.

MODEL G-3 — 100 to 400X \$64.50
Triple divisible objective. Substage diaphragm turret. Most economical high school microscope.

MODEL S-2 — 75 to 250X \$37.85
Double divisible objective. Simple and efficient for elementary science use.

MODEL A — 15, 45 and 75X \$54.85
Study, standard-sized, with wide field, sharp vision. Excellent for nature study.

SUBSTAGE LAMPS and other ACCESSORIES

Write for literature to Dept. SNL

TESTA MFG. CO.
10122 E. Rush St., El Monte, Calif.

U.S. ARMY AND NAVY MEDICAL SURPLUS

Brand new, first quality physicians and surgeons precision instruments which can be used in other fields. Order by mail, money back if not completely satisfied. All items are postpaid.

4 TURRET 600X — 25X RESEARCH MICROSCOPE

Value is at least three times more than this low price **\$22.50**

Full 11-inches High! 4 Lens Rotating Turret! Rack & Pinion Focusing! 5-Stop Light Control!

Premium full-size imported professional microscope, same type used in university and research labs! 3 eyepieces, 2 ocular lenses combine with 4 objective lenses on click-stop turret to yield 8 MAGNIFICATIONS from 600X to 25X! Lens mount and 3 1/4" x 2 3/8" stage tilt FULL 90°! Both flat AND concave sub-stage mirrors; illumination can be "stopped down" with 5-hole sub-stage light control adjustment! Black satin finish, metal construction. Precision ground and polished achromatic lenses. Complete with fitted, wood case; specimen slides, hard to duplicate anywhere at this exclusive bargain price. Our Price **\$22.50**

SCOPELITE SUBSTAGE LAMP gives portable illumination for microscope, etc., \$5.00
12 PREPARED SLIDES of little animals in slidecase..... \$2.25

U. S. MEDICAL CORPS PROFESSIONAL STETHOSCOPE. Combination Ford-Bowles flat diaphragm type

2 in 1 stethoscope, interchangeable. For physicians, electronics, engineers, and industrial uses. Ideal as an educational gift. Lists for \$12.00. Our price **\$4.75**

SPHYGMOMANOMETERS

MERCURIAL TYPE Guaranteed accurate, hook-on cuff. Durable, lightweight metal case, artistic grey finish. List \$38.00. Our price **\$21.50**

ANEROID MODEL
Hook-on Cuff in genuine leather pouch for easy carrying. **\$19.50** each
Both Sphygmomanometers are guaranteed for 10 years.

U. S. ARMY MAGNIFYING GLASS

In plush-lined green velvet case—leather covered

High-power glass. Distortion-free. Polished chrome frame. Finest rugged American-made. Precision-ground and polished lens 3" diameter. Reg. \$12.00.

An unusual buy at... **\$3.80**

MAGNI-FOCUSER

New 3D Binocular Magnifier for close work Ground from the finest optical glass, each lens is a ground prism for perfect 3D Binocular magnification. Adjusts to all head sizes. For physicians, industrial, re-touchers, unlimited uses for all precision work. Regular stock.

Model No.	Magnifies	Price
2	1 1/2 times at 20"	\$10.50
3	1 3/4 " " 14"	\$10.50
5	2 1/4 " " 10"	\$10.50
7	2 3/4 " " 8"	\$10.50
10	3 1/2 " " 4"	\$12.50

CRAFTSMEN, HOBBYISTS and PROFESSIONS
Write for our catalog L-3 on medical surplus items describing uses in other fields.

Physicians and Hospitals write for our government Surplus Catalog 145-SN on your letterhead—lists more than 7500 surgical and hospital items.

TERMS: Cash with order or C.O.D. Open account to physicians, hospitals and firms.

ARISTA SURGICAL COMPANY Dept. 145-SN, 67 LEXINGTON AVE., NEW YORK 10, N. Y.