

February '95

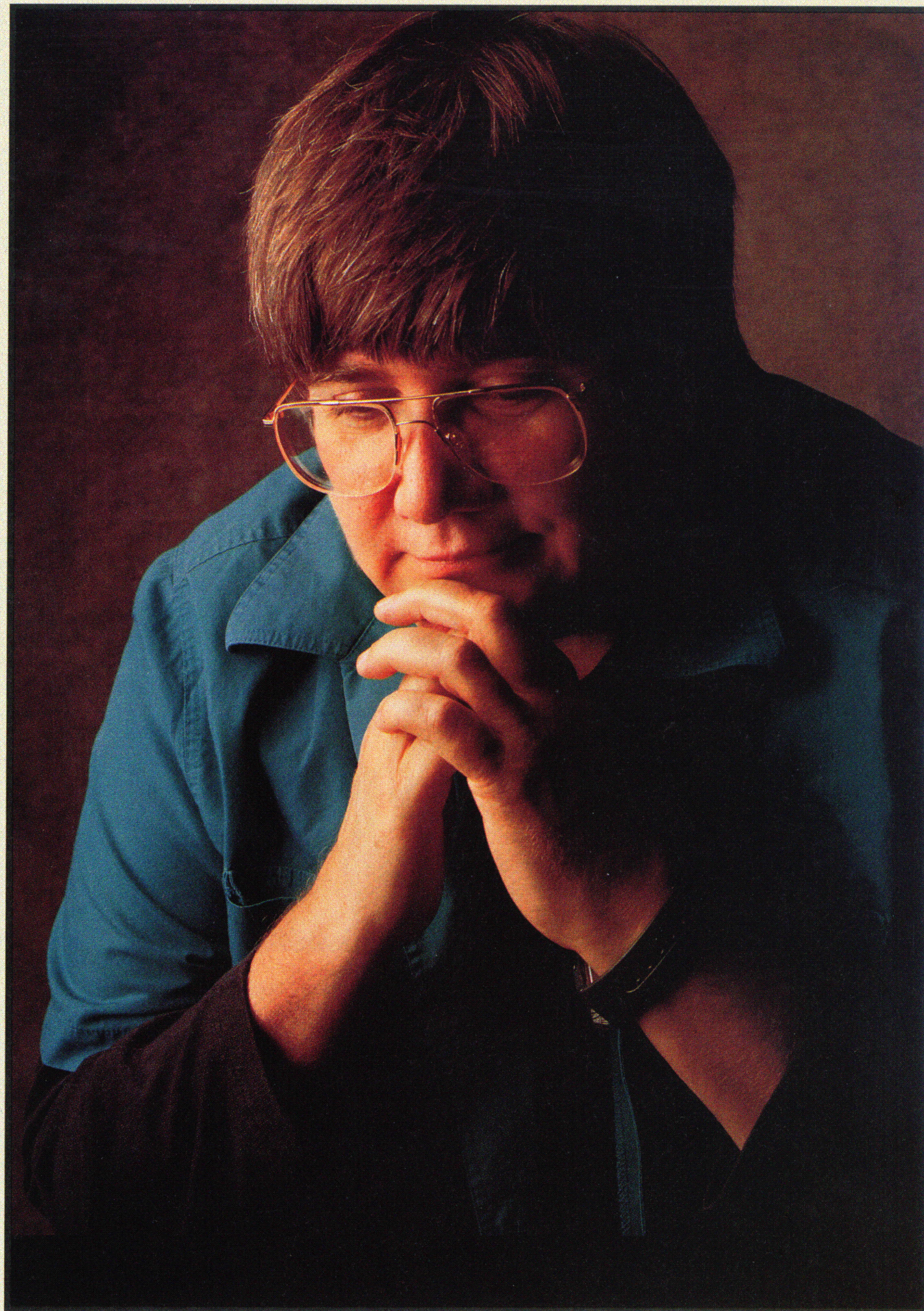
## INTERVIEW

A scant generation ago, scholars painted a utopian vision of the ancient Maya, whose civilization flourished in Central America from 200 to 900 A.D. The Maya were portrayed as nature-loving pacifists, so immersed in philosophical thought they remained unmoved by power, lust, or greed. Their cities of magnificent pyramids, wide plazas, and ballcourts were envisioned as sanctuaries where astronomer-priests contemplated the heavens and the endless progression of time. The cryptic writing adorning Mayan architecture, so the experts proclaimed, had nothing to do with history. The deeds of men, they assumed, held no interest for these star-dazed hippies.

We now know this picture is dead wrong. If any person has been instrumental in exploding this myth, it is Tennessee-born Linda Schele, a large-boned woman with a bawdy sense of humor and a dazzling facility for teasing the hidden meaning from the labyrinthine symbols the Maya used to record their language. In the early Seventies, seemingly out of nowhere, she burst into the field of Mayan studies and with her collaborators transformed our understanding of Mayan beliefs and practices.

Previously, experts could decipher only dates encoded in elaborate hieroglyphic signs; now they

**SHE ENCODED AN ANCIENT LANGUAGE, SO AFTER CENTURIES OF SILENCE, THE MAYA SPEAK AGAIN.**



# LINDA SCHELE

PHOTOGRAPHS BY WILLIAM COUPON

read more than 90 percent of some texts. The words in the inscriptions can actually be intoned just as the ancients would have pronounced them. After centuries of silence, the Maya speak again. And what they say is not what Schele's predecessors expected to hear. Formerly cast as the Greeks of the New World, the Maya were actually more like Romans. They loved pomp and pageantry and relished bloodletting on the battlefield, playing ground, or ritual altar. As Schele puts it, "Blood was the mortar of their society."

Like Jean François Champollion of Rosetta Stone fame, Schele follows a long tradition of epigraphers—experts in deciphering lost writing systems—who started as amateurs. In 1970, as a fledgling studio art teacher in Mobile, Alabama, she, her husband, and three students visited Mexico's Mayan ruins over Christmas vacation. Arriving at the ancient site of Palenque, the group planned to stay the obligatory two hours recommended in their travel guide. Instead, they spent over 12 days. What began as a standard tourist jaunt became for Schele a lifelong obsession.

Schele returned to Palenque each of the next three summers, befriending scholars, knowledgeable laymen, and anyone else who could offer her insights into the vanished society. Eventually the Scheles bought a house in a neighboring village so she could start mapping Palenque's sprawling vine-covered structures. Three years later, Schele made a formidable impression at an international gathering of Mayanists held near the ruins. After brainstorming with Peter Mathews of Calgary University for just three hours, the duo presented stunning insights into the structure and grammar of the Mayan written language. They also put together 200 years of Palenque's dynastic lineage, spanning the lives of six successive kings—the most complete list of rulers for any Mayan site. "History had been made before our very eyes," recalls Yale Mayanist Michael Coe.

As Schele, Mathews, and others extended and elaborated their approach, the trickle of decipherable glyphs swelled to a torrent. Fragments of texts came together into compelling passages of prose. Along with archaeological finds, these reveal an epic warring of Maya dynasties. The glyphs also provide clues to the sudden, mysterious

### **JOB DESCRIPTION:**

Epigrapher, teacher, leading spokesperson for the Mayan world view

### **INFLUENTIAL PUBLICATIONS:**

*The Blood of Kings: Ritual and Dynasty in Maya Art* with Mary Miller and *Maya Cosmos: Three Thousand Years*  
*On the Shaman's Past* with David Freidel and Joy Parker

### **WHY THE GLYPHS ARE LIKE THE JEFFERSON MEMORIAL:**

If our only record of American history were what's written on monuments in Washington, you wouldn't find out much about the average American. Similarly,



there's much the Maya did not write about: taxes, trade, thoughts about everyday life. But we can learn who was victorious in war and had the power to commission public monuments and buildings—or at least what they wanted to tell about themselves.

### **FAVORITE MAYAN BUILDING:**

Temple of Inscriptions at Palenque

### **A LESSON FROM A LOST CIVILIZATION:**

In the end of the Mayan empire so many resources went into warfare the whole social structure became unstable. The question for us is whether the 1980s administrations spent us into oblivion as well.

collapse of the empire, and bear testimony to exotic religious attitudes, shamanistic traditions, and social customs.

Epigrapher Schele is also professor of art history at the University of Texas in Austin, where her annual Mayan hieroglyphics workshops attract hundreds of professionals and lay people. A natural showman, she relishes drawing sweeping parallels from past to present. "Schele has emerged as perhaps the most prominent spokesperson of the Mayan world view," observes Princeton Mayanist Gillett Griffin. The very qualities that make her a successful popularizer, however, make her vulnerable to criticism. Some scholars attack her for being wild and woolly with her facts—or implicitly too colorful. Others, from the archaeological camp, often say Schele and fellow epigraphers' reconstructions of Mayan history rely too heavily on inscriptions which, they argue, are largely the propaganda of the noble classes. While conceding their point, Schele responds, "Of course their history was biased. So is ours. There's still much we can learn from it."

To interview Schele, Kathleen McAuliffe traveled to Antigua, the old colonial capital of Guatemala, where the historian, now 52, was on a mission to teach modern Maya the lost writing system of their ancestors. Schele and McAuliffe talked over the span of a week with frequent stops and starts to accommodate the endless stream of Maya visitors seeking Schele.

**Omni:** Tell us about that first epiphany at Palenque.

**Schele:** It was like a dream. You see about 15 pyramids with huge, knee-high steps leading to their tops, silhouetted against forest-covered mountains. The cicadas start with one song, then another answers, and another, until it becomes a 12-tone harmony. Creeks tumble down the mountainside. Where water bubbles out, the mountain is streaked with limestone. No one knew a single person who had ever lived in this mystery place. It was the most beautiful and sacred place I'd been in my life. I had to find out more about it.

Although no one knew it, the field of Mayan studies was about to crack wide open. Not only did I arrive at the right place at the right time, I met the right anthropologists, zoologists, and

historians. There was no reason for these people to welcome a little ol' Southern girl who'd just gotten a Master of Fine Arts and was teaching at the University of South Alabama. But they didn't care about my credentials. They taught me with generosity and humor, and if I had a good idea, they said, "Wow! Yeah!" and encouraged me.

**Omni:** So nothing was known about Palenque at that time?

**Schele:** Every guide made up his own story. By 1970, the great tomb in the Temple of Inscriptions had been found. Many believed it showed an astronaut taking off. In the images on the walls people saw astronomer priests or maybe a god. In the palace's southern wing was a bench palace where guides claimed the king took the virginity of all the young girls in the city. A huge vacuum existed, and people fed into it whatever they wanted.

**Omni:** What function did the pyramids, the courts, and other structures found at Palenque have?

**Schele:** The pyramids were, in their words, sacred mountains. Mayas saw the world as this mountainous thing on the back of a turtle floating in the primordial sea. The courts below the pyramids were the valleys. Near the main court would be a ballcourt, repre-

senting an opening or crack leading to the Otherworld. The royal family lived in palaces nearby. On important occasions—holy days, celebrations of a battle victory, the birth of an heir—the king and queen went into the sacred house on top of the pyramid where many rituals took place, including the torture or sacrifice of war captives, and they'd communicate with the Otherworld. Then they'd come out in front of the crowd and perform bloodletting rituals on themselves.

**Omni:** So it is thought they were a pretty violent culture?

**Schele:** They weren't especially bad—or good. They were not idyllic nature-loving people who never hurt anybody, nor were they bloodthirsty sacrificial priests who consumed human beings by the thousands.

**Omni:** But you said "Blood was the mortar of their culture."

**Schele:** It was. But put this in a different light. If you're a devout Christian, how do you save your soul? By leading an exemplary life—giving away everything you've got. Maya gave what to them was the most precious substance of all, their blood. From a symbolic perspective, the two most important parts of the human body are the tongue—where intelligent communication

comes from—and the genitals. Those are the parts from which they ritually drew blood.

The Mayan king made the most powerful sacrifices. Our presidents, chancellors, and prime ministers engage in political battles and send 19-year-olds in their place to fight a war. Not only was the Mayan king on the battlefield til the day he died, but he had to open his tongue and penis every time a major ceremony or event took place in the center. Now, can you imagine how many Clintons we'd have if, at every major meeting of Congress, at every important event, he had to drop his pants and push a great needle through his dick in public? We wouldn't have many men wanting to be politicians; and those who did would be very careful!

**Omni:** The king poked a needle through the central shaft of his penis!

**Schele:** Through most of the man's life, the needle—a bone awl—was poked through the skin and top of the shaft in much the way aborigines scar themselves. There were three diagonal slicing scars across the top of the penis. When a person was taken captive and was going to be killed, it was far more severe. They could be emasculated.

**Omni:** Even in the "milder version," wouldn't this interfere with a man's sexual enjoyment or reproductive ability?

**Schele:** No. The Australian Aborigines split the penis along the bottom so it splays out like a cut weenie. According to one anthropologist, Aboriginal women much prefer scarred men. It makes the penis much bigger.

**Omni:** What was the underlying meaning of bloodletting?

**Schele:** A fundamental principle of ancient Mayan beliefs was the idea of reciprocity: The gods of the supernatural world cannot exist without human intervention through ritual and offerings. And humans certainly cannot exist without the intervention of the gods who bring rain, make food grow, and create new life. Underlying bloodletting as a central act of piety, is the concept of *ch'ulel*. To both the ancients and some modern Maya such as the Tzotzils of the highlands of Chiapas in Mexico, *ch'ulel* is a living force permeating everything. They see the entire cosmos is imbued with life. Houses, mountains, springs, sacred places—all have *ch'ulel*. The most important interactions are not between human and human, human and place, human and animal, but between the *ch'ulel* of those things. This force is indestructible and composed of 13 parts. When you are sick, climax in sex, are terribly frightened—these kinds of situations—



## THE ENGINES OF GOD

BY JACK McDEVITT

Review by Andrew Wheeler

Like most SF readers, I started young. I'd read everything in the (admittedly small) "sci-fi" section of my junior high's library before 6th grade was over. I read all the SF classics, and many not-so-classics, and some of the books have stuck in my head ever since, though their titles haven't always stayed with me. But my favorite was about a teenage boy who was with an interplanetary archaeological team. They found working alien artifacts, which led them (after whizzing all over the galaxy to discover other wonderful things) to meet the aliens. I loved the book at the time and I've had a soft spot for alien archaeology ever since.

So I had high hopes for this book, about archaeological investigations into three different dead alien races (two of them medium-tech single-planet civilizations that disappeared mysteriously). McDevitt didn't let me down; I was intrigued by the various structures left behind by the enigmatic "Monument-makers" (the third, galaxy-spanning, race) and caught up in the race to excavate the ancient Temple of Winds on the planet of Quaraqwa before the Kozmik conglomerate began terraforming and destroyed it all. It's a story of discovery, of learning the true history of the past and of alien civilizations. That, to me, is the pure core of SF.

I certainly won't spoil it by telling you whether any aliens turn up alive or not, but I will say it reminded me of that long-ago book. What I loved about both of them was the exploration: how each artifact led to another, to a new discovery. I've heard a lot of grumbling lately that there's no "sense of wonder" in SF anymore. Well, there is: it's right here.

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you can lose a piece of that soul to the Earth Lord. Then you have to go through ceremonies to get it back.

In the human body, *ch'ulel* resides in the blood. When the Mayan king and queen emerged from the inner sanctum on the top of the pyramid to give a blood offering, the entire community would gather below. They would have already gone many days without sleep or food, possibly dancing the entire time; they'd have taken very hot steam baths. Many would drink *chicha*, a semifermented beerlike drink, and perhaps they'd process hallucinogens through enemas made of hot water mixed with tobacco or other plants.

**Omni:** You can hallucinate on tobacco when taken in enema form?

**Schele:** Major hallucinations. Tobacco is the sacred plant of all Native American peoples and is widely used to induce trances. Native American tobacco has a nicotine content as high as 18 percent. The stuff we smoke is three percent at best. They also smoked big cigars, chewed, and perhaps even ate tobacco. They also hallucinated on psilocybin mushrooms and possibly mountain laurel or a plant similar to it. Around the world mountain laurel has been known to induce visions of serpents. Such a vision figured prominently in the Maya bloodletting ceremony. As the king and queen ran ropes through their tongues, and the king pierced his penis, they'd see a snake, a conduit leading them to the Otherworld. In their rapturous trance, the snake reels up with its mouth open, and within is the spiritual being the king and queen talk to.

**Omni:** Did commoners engage in bloodletting rituals?

**Schele:** All humans can be conduits to the Otherworld. The sacred ritual the king did in the center was the same as a farmer's in his household. But the rulers were thought to be especially potent—people who could handle the most powerful energies. The Maya then and now view supernatural forces as extremely dangerous, so the person who unleashes them can do as much harm as good. But the common people had ancestors, too. Even today, the Tzotzil say if you don't pay attention to your ancestors, they'll release your animal spirit companion, and it will wander the world without protection and get hurt, and that will make you sick.

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dating from the Spanish invasion.

**Omni:** Wait—the Maya civilization collapsed in 900 A.D., and the Spanish didn't arrive until the 1500s. Who told the Spanish about their culture?

**Schele:** Just as the Italians didn't go away when Rome collapsed, the Maya didn't vanish when their tenth-century kingdom collapsed. Today they are in the Yucatan, Belize, and highlands of Guatemala in the millions. The records are so valuable because there were still some literate Mayas. Only instead of carving inscriptions on stone tablets, they'd switched to exquisitely painted books of beaten bark.

Within two centuries of the invasion in the 1500s, the last vestiges of the literate elite died off, either victims of the Spaniards' swords or, more often, European germs. But before they died, the Spanish studied their beliefs in order to convert them. And although the Spanish torched virtually all the thousands of books in America's first library, four survived. Three were apparently sent by Cortes and others to the king of Spain as booty, and later were dispersed to different owners.

**Omni:** How did these documents help break the Mayan code?

**Schele:** In the 1860s and 1870s, scholars found the first Bishop of Yucatan's written description of the Maya, including an analysis of how the Maya calendar worked. The Dresden codex, another critical document uncovered around the same time, was used by diviners to keep track of days and make prophecy. These and other sources enabled scholars to work out the fundamental of their calendar system, leading to a view, dominant in the Fifties, that the Maya dedicated all their energy to mathematics, stargazing, and recording the passage of time.

In the late Fifties, archaeologist Heinrich Berlin figured that several glyphs recorded names of people and sites, which ran contrary to the view that there was no historical content to the writing. The most devastating challenge to the reigning view came in a 1960 article published by Tatiana Proskouriakoff of the Carnegie Institute. At a Guatemalan Maya site, Piedras Negras, were a series of monuments set up in rows in front of different buildings. She noticed the dates on these rows of monuments always spanned a period of less than 60 or 70 years; the imagery on the stellae [carved stones] recurrently had the same theme; the earliest date had one glyph associated with it, the next date some 20 or 30 years later, another glyph; and the last date was associated with still another glyph. She proposed the first date was

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ponents of Mayan punctuation. The Maya love to say, "So much time after such and such a thing had happened, and then something else happened." The "had" part and the "and then" part are always the same—road maps through the chronology. Although there are no periods, semicolons, or commas, specific glyphs highlight the beginning and end of a sentence. A sentence typically begins with the verb first and then object and subject. "Planted the tree John."

Once we realized that, we could say, "Okay, we may not know this word, but it must be a verb. It has to be action. What is the political context?" We could build up fields of meanings that limit what the sense can be. We know the sound value and meaning of maybe 50 percent of the signs. Including glyphs for which we know the part of speech they represent and have a general idea of their category of meaning, then we know maybe 75 or 80 percent. Once you know their writing records actions in the lives of nobles and kings, and where the verbs are, you can begin to reconstruct history.

**Omni:** What special talent does it take to be a good epigrapher?

**Schele:** Good visual pattern recognition and memory. Most epigraphers keep 500 to 800 inscriptions in their heads at all times. Plus, you need to know the context in which you have seen those inscriptions. We're the kind of people who remember where a passage in a book is by how thick the book was, how deep we were into it, and where the passage fell on the page. You also need an ability to see connections between things. There's a playfulness to it; all great epigraphers are cat lovers.

**Omni:** Tell me about the extraordinary Maya ball games.

**Schele:** Every city had an I-shaped ballcourt ranging from about the size of a volleyball court to as big as a football field. Pictures of the game reveal one-on-one competition and teams of up to 11 players. The ball was larger than a basketball and made of solid rubber that would've bounced like hell. It probably weighed up to 40 pounds, so if it hit you at high speed, it could kill you. The competitors wore padding and a U-shaped protector called a yoke around their hips. We know nothing about the rules, but all rubberball games we play today—basketball, soccer, football—descend from Mesoamerican ball games.

**Omni:** Their ball game sounds like an institution as big as the NBA or NFL.

**Schele:** You bet—even bigger. The symbolism and meaning of the game

are contained in the Mayan version of "Genesis," the *Popol Vuh*. This is the story of two sets of Hero Twins, largely played out in the arena of the ball game, where the twins encounter the forces of life and death. The first set of twins, the maize gods, are called to the Otherworld because they disturbed the Lords of Death playing their ball game. The lords kill them both, burying one of them in the floor of the ballcourt of the Otherworld, and hanging the skull of the other twin in a gourd tree as a warning against disturbing the lords.

The daughter of one Death Lord walked by the skull, which spit into her hand, thus impregnating her. Immaculate conception, right? She gave birth to another set of twins, who also disturbed the Death Lords during their ball game. They, too, were called to the Otherworld, where the lords put them through a series of trials. Each time the twins miraculously outwitted the lords despite overwhelming odds. These tests culminated in the death of the twins, but they came back to life, disguised as great dancers and magicians who could sacrifice themselves and not die. They were called to perform before the Lords of Death and were so good the lords asked to be sacrificed to see what it was like—only they didn't come back to life. This foundation myth explains how the ballcourt came to represent the crack in the earth leading to the Otherworld. The ball game is a metaphor for the fight between good and evil, life and death, signifying that by yielding to sacrifice, people achieve resurrection.

**Omni:** Who competed in the games?

**Schele:** The teams could be regular people playing for fun, or allies seeking closer ties. Political alliances could be sanctified in the game because allied nobles entered the Otherworld through the ballcourt to talk to the gods and ancestral dead. In the most sacred games, nobles were pitted against high-ranked war captives, and they played for life-and-death stakes. These games were probably rigged so the home team won, but there was the distant possibility that an underdog would win. The loser presumably journeyed to the Otherworld as a messenger for the victor and was possibly buried in the floor. If the war captive won, his reward would be eternal glory, but he'd still be sacrificed, often after an extended period of torture. Especially important captive nobles were kept alive for 16 or 17 years for harvesting—blood was taken from them.

Before you get too heavily into the horror of this, remember Spanish Inquisitors tortured innocent people for

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the good of their souls until they confessed to being witches, then paraded them through the streets in what later became the Ku Klux Klan outfit, and finally burned them at the stake. Between 1481 and 1540, some 20,000 people were brought before the Inquisition in Seville alone. The numbers tortured or killed were within the range of sacrificial deaths in the New World.

*Omni:* What led to the civilization's collapse?

*Schele:* The growth of the noble class had a lot to do with it. Art historian Mary Miller calculated that if you start in the year 600 with a single noble husband and wife with four children who survived until adulthood, and they had four children who survived, and so on, by the year 800 there would be 700 people who had the right to claim noble status. So the percentage of people of high status grew rapidly along with the demand to access the kinds of goods and privileges that marked them as noble. This resulted in more and more kingdoms, competing for fewer and fewer resources, with less no-man's land between them. The rise in warfare, coupled with overpopulation, put a tremendous strain on the agricultural system. There was massive deforestation in the final years. I imagine the end was pretty gruesome.

We don't know what actually pushed the Maya civilization over the edge—whether it was a major war, series of droughts, or just one strain too many. There comes a point when there's so much stress on the society that, as my colleague David Freidel says, it just becomes pathological. We saw that with the former Soviet Union: It wasn't a slow gentle deceleration. It was boom. Two years and the empire was gone.

*Omni:* You've argued that Mayan customs and beliefs have survived despite centuries of oppression following the conquest. Isn't that a radical notion?

*Schele:* It's mind-blowing to some scholars. The perception has been the conquest was so traumatic—between the deaths from disease reaching 90 percent among Native Americans and the violent suppression of the people—that their world view could not have survived. But it's my opinion that, fused with an overlay of European customs and religious beliefs, there is a profound, amazingly intact, pre-Columbian core underlying it all. Numerous beliefs, legends, and shamanistic traditions are alive and well.

Many other contemporary examples of Mayan belief and practice represent an unbroken heritage spanning around 3,000 years.

*Omni:* By teaching the ancient writing

system and making ancient material accessible to modern Mayas, you've said that you hope to enable them to enter the dialogue of history. How so?

**Schele:** History is a phenomenon living people invent and create to establish who they are based on what they think they were in the past. The history of events can never reach objective truth because each generation has to rewrite history, adjusting it to their own expectations and experiences. Native Americans have not been able to contemplate their history in their own words and from their own point of view for 500 years. So these writing workshops provide an experience of profound importance to them.

Suppose the Russians had invaded the United States and set up a Soviet United States for 500 years and told Americans everything they were came from Marxist-Leninist thought. There was no American Revolution, no great presidents, that Americans were in fact a creation of their conquest by Russia. Then one day some people came with a copy of the U.S. Constitution, Declaration of Independence, books about Washington and Jefferson, and said, "Hey, maybe you want to read these?" Most Maya are desperately hungry to learn about their heritage. Of course I get tremendous back in return. They speak these languages. We don't.

There are 28 Mayan languages still surviving. Those closest to the ancient languages are Yucatec, spoken in the Yucatan, and Chol, spoken near Palenque. The difference between Yucatec and Chol of today and the languages recorded in the inscriptions is roughly that between Chaucer and modern English. During the workshops, the Maya often say to us, "You're asking us to recall obscure words and expressions—the kinds our grandfathers might have used." Sometimes they don't have the word at all, but frequently we find either the same word root or a close equivalent.

**Omni:** Recently you have reached a new level of understanding of the *Popul Vuh*. What is the breakthrough?

**Schele:** By chance, Freidel and I discovered that all these events described as myth are really maps of the sky. The Creation myth can be traced back at least as early as the second century B.C. and describes the acts of the gods on two days—August 13, 3114 B.C., and February 5, 3112 B.C. On the first day, the gods laid the three stones of the cosmic hearth. Maya women traditionally cook on a hearth made of three stones. The Maya also see these three stones as the three stars in the constellation Orion.

In a Maya house, fire is built between the three hearth stones and a large flat clay plate laid on top of them. The woman grinds corn, makes it into a dough, pats the dough into tortillas, then places them on the clay plate over the hearth. The tortillas balloon up to form a *panza* or "belly." The Maya see the tortilla as an analog of a human being. The original human beings were made from maize dough in exactly the same way by the grandmother of the Hero Twins. So everyday of her life a woman wakes up, creates food for her family, and replicates at her hearth the acts of creation.

On February 5, more than a year after the first hearth was laid, the gods lifted up the cosmic tree. This is also visible in the sky. The tree is the Milky Way. In 3112 B.C., at about 2:00 in the morning of February 5, the entire Milky Way rose out of the eastern horizon, until at dawn it stretched north to south across the sky. In several Mayan languages, the verb "create" is also "to dawn." At the base of the tree is what we call the constellation Scorpion. The Maya also saw the picture of a scorpion and called it any of a dozen of their words for scorpion. On August 13, the cosmic hearth rolled up to the center of the sky at dawn, and on February 5, the Milky Way really was erected in the sky. These events were real.

I can't tell you what a revelation it was to discover their myths were not just stories but actual sky maps. My God! They were doing with their creation myths what Einstein was doing with his formulas. These myths are great overarching symbolic arrays expressing their understanding of creation—their version of what modern cosmologists call the Big Bang.

**Omni:** What can contemporary civilization learn from the rise and fall of the Mayan empire?

**Schele:** The final episode in the story of creation in the *Popul Vuh* has the gods creating human beings out of maize—creatures so perfect they understand the world with the same clarity and insight as the gods. Humans' power frightened the gods, but instead of destroying us, they gave us myopia so we could only understand what's very close to us. Isn't that the perfect metaphor? We can't see beyond our immediate interests and goals. That's what ultimately brought about the demise of the Maya, and it could well be our downfall, too. Except we still have a ways to go to emulate them. The United States has existed a bit over 200 years. Their civilization was enormously successful from 500 B.C. to 900 A.D., a span of 1,400 years. ☐

## STARS

CONTINUED FROM PAGE 20

Earth wouldn't have begun in the first place." Although our galaxy contains supernovas—violent explosions of dying stars—"they're simply not energetic enough to do the job," Loh adds. The shock wave from a supernova might accelerate a particle to about  $10^{16}$  eV at the very most, he estimates, far short of the highest observed values.

A very large black hole, however, could impart the tremendous amounts of energy required—in the neighborhood of  $10^{20}$  eV. The more massive the black hole, the more energy it puts out in the form of radiation. According to this scenario, matter falling in toward a black hole runs into a tremendous blast of radiation pouring out. When these two waves (matter and radiation) collide, they create a shock wave capable of accelerating particles to incredible energies—tens of millions of times higher than those reached in manmade particle accelerators.

The Giant Array just may point to the centers of active galaxies harboring massive black holes. It's conceivable, on the other hand, that cosmic rays simply fly into Earth from all directions, without indicating a specific source. Cronin calls this the "dullest possible result," but his University of Chicago colleague David Schramm considers it the most tantalizing possibility. Such a finding would support Schramm's theory that the highest-energy cosmic rays are produced by the decay of relics from the Big Bang called "topological defects." The idea is not preposterous, according to Loh. "If we cannot correlate cosmic rays with any particular galaxy or black hole, who knows, maybe they are from topological defects." The notion is speculative, however, since no one has ever proven the existence of topological defects.

"Regardless of whether it's our theory, 'rotting defects,' or something more mundane like black holes, it will be very exciting," Schramm says. "Let's face it, when you consider a black hole the 'mundane' source, you know you're talking about something exciting." ☐

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