Sunwatchers of the American Southwest

Centuries ago, inhabitants of New Mexico and Arizona made a large number of simple solar observatories

In the Cave of Life in the Petrified Forest in Arizona 45 days before and after the winter solstice a dagger of sunlight at sunset fades out pointing to the center of the cross (above). At winter solstice at a site in Painted Rock State Park, Ariz., an arrow of sunlight points to the center of a circle (below).

Photos: Robert and Ann Preston

By DIETRICK E. THOMSEN

Many rocky sites in the southwestern United States are adorned with petroglyphs, pictures scratched in the rock centuries ago by Native Americans. Some of the figures are abstractions; some are symbolic representations of human or animal figures. Archaeologically and anthropologically the usual assumption is that such pictures are not made purely for decorative or aesthetic reasons. A social function is looked for.

A few years ago, an observer named Anna Sofaer found that certain petroglyphs at Fajada Butte in Chaco Canyon, N.M., seemed to be markers for important dates in the sun's annual cycle (SN: 8/26/78, p. 148). On the solstices or the equinoxes "daggers" of sunlight formed by the shadows of adjacent rocks would fall on the centers or other prominent points of certain figures. Sofaer and collaborators found enough such instances at Fajada Butte to convince them that one of the purposes of the place was to serve as a kind of solar observatory.

One such site might constitute some kind of anomaly. Now it is joined by 19 others scattered around Arizona. Eighteen of these newly found sites are, like Fajada Butte, apparently the work of the Anasazi people, who inhabited the region from about the year 700 to the year 1300. The nineteenth site, at Painted Rocks State Park near Gila Bend, in southwestern Arizona, probably belonged to the Hohokam people, who were more or less contemporary with the Anasazi.

Evidence for sun-petroglyph interactions at these new sites has been gathered by a husband-and-wife team, Robert A. Preston, supervisor of the Astronomical Measurements Group of the Jet Propulsion Laboratory in Pasadena, Calif., and Ann L. Preston of the California College of Arts and Crafts in Oakland. They have spent a good deal of their spare time in the last few years gathering data in the Arizona desert. Eighteen of their sites, all except the Painted Rocks one, are in or near the Petrified Forest National Park.

The Prestons presented their findings at the meeting in Boston of the American Astronomical Society and have submitted them for publication in SCIENCE. At the meeting they showed both still pictures and time-lapse motion pictures of the sunlight-petroglyph interactions. The motion pictures are particularly dramatic, showing shadows or daggers of light sweeping across the rock figures until, on the appropriate day, they touch certain points on the figures. The figures are mostly spirals and circles. Human and lizard-like figures make up 16 percent, and four percent are crosses. In the circles, spirals and crosses, the reference points may be the centers or the edges. In the lizards they are usually the tip of the tail; in the humans the tip of the penis. "Tail," says Robert Preston, "may be a euphemism."

In addition to situations in which shadow or light moves across a figure, there are those where the observer places an eye against the figure, and then, at sunrise on the relevant day, a spot of light can be seen through a notch or hole in another rock. The dates marked are the solstices, the equinoxes and a day 45 days (one eighth of a year) before and after winter solstice.

The Prestons say they were inspired to look for a multitude of sites to determine whether sunwatching was a purposeful and widespread activity of Americans of that time and place. "Only when multiple occurrences of a particular solar interaction are found can one be sure the interaction is purposeful," they write. "To this end we studied every principal petroglyph site of Anasazi origin we could locate or conveniently work within a specified geographical region."

Using a computer they calculated precision azimuths and elevations for both the sun and the moon at the location of their base sample, an area of northeastern Arizona 10 kilometers by 25 in extent, and made plots of the sun's daily path through the sky on five relevant dates, the solstices, equinoxes and the 45th day after winter solstice. This way they could predict petroglyphs likely to have the proper interactions. Not all the drawings function as astronomical markers. Some seem to have been related to fertility ceremonies. Ann Preston says they had to be careful making pictures for public display, as many of the solar markers are surrounded by drawings of a pronounced erotic character.

Within a few years it is difficult temporally and logistically to be at so many sites on just the proper days, so certain substitutions in technique were made. Observations can be made within 3.5 days around the date of a solstice with an error of no more than 0.05° in the declination of the sun. Such observations are good enough for the purpose, since the sun's track in the sky will have shifted more than that in declination since the petroglyphs were made. (The angle between the sun's track in the sky and the earth's equator — that is, the sun's declination — changes 0.12° per millenium. In one millenium or so that is not enough to destroy the sun-petroglyph relations at these sites.)

At other times observations may be made on a day close to the desired day, and predicted or observed motion of the sun's position be used to compensate. Finally, the moon may be used when it happens to stand at an important solar position. "The moon has just reached the declinations of the summer and winter solstice sun for the first time in nine years," Preston and Preston point out. "This will happen every month for the next nine years."

Even so, time was short, and many sites had to be investigated. The program depended, therefore, on accurate prediction of which petroglyphs were likely to be solar markers. Nevertheless, the Prestons say, "no solar interactions have been claimed unless we observed them."

Their work now indicates that solar observatories of the sort were numerous and widespread in Arizona, and they refer to related findings in California and the Baja California peninsula. One of their comparisons of sites at opposite extremes of the territory they searched runs:

"[At the Painted Rocks site] 45 days before or after winter solstice two pointers move from left to right across the rockface. The leading tip of the first pointer brushes tangent to the lizard's body. The leading tip of the second pointer intersects the center of the cross. . . .

"On this same day in the Cave of Life, 350 km to the northeast, the trailing tip of a pointer dies in the center of a cross at sunset. In both instances, the cross interactions happen only on that day."

The petroglyph makers seem not to have altered the natural rock configurations. They seem to have taken note of fortuitous plays of light and shadow on the appropriate days, and drawn in their markers to fit.

"Archaeologists are going to be busy," says Curtis Schaafsma, director of the Laboratory of Anthropology at the Museum of New Mexico in Santa Fe and State Archeologist of New Mexico. As a result of the Prestons going around and finding empirical correspondences of this sort, they have provided a large data base, he says. Archaeology "has to assimilate a large block of information," and produce meaningful and coherent models to explain it, possibly hypothesizing a prehistoric religion that would account for it.

The Prestons' work "has considerable value," says Fred R. Eggan, retired head of the Department of Anthropology at the University of Chicago, now a resident of Santa Fe. Eggan thinks it particularly important that the data were compiled "out of [Robert Preston's] astronomical knowledge."

The modern Hopi and Zuñi, whom Eggan has studied for decades, also do a lot of sunwatching. They have a lunar calendar that has to be fit to a solar year, because the sun governs their agriculture, which is precarious. Eggan points out that the Hopi and Zuñi must live with a season of about 130 days to grow corn, "caught between last and first frost." In a situation as tight as that, they "have to predict when to start planting in order to get through." The sun is more accurate for that than the daily vagaries of the weather. In the same region, with very little climatic change over the last thousand years, the Anasazi would have been under similar constraints.

In modern Zuñi and Hopi society, each pueblo is autonomous, and each does its own sun-watching and keeps its own calendar. If the Anasazi were organized like their modern descendants, they too would have needed a lot of fairly simple sunwatching sites, one for each group or pueblo. (Schaafsma, too, stresses the need for a lot of observatories to serve each independent pueblo.) This is just what the Prestons have found, Eggan points out: "a whole series of simpler models [than Fajada Butte]. There's no doubt that they are genuine and culminated in a more sophisticated observatory on Fajada Butte." □

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Recent work by Duvall, and J.W. Harvey at Kitt Peak National Observatory in Tucson, Ariz., and by Duvall, Harvey and Martin Pomerantz of the Bartol Research Foundation in Newark, Del., at the South Pole, may provide some of these observations. Reporting on their preliminary results in the March 3 NATURE, Duvall and Harvey say they have observed p-mode oscillations for the first time from degrees 6 to 140. The higher the degree of the oscillation, the deeper within the sun the oscillation penetrates, and the more information about the sun's interior it brings.

One question on which these data may shed light is the abundance of helium and heavy elements in the sun's core. How the sun burns hydrogen to form helium and heavier elements is poorly understood. There exists a model of the process that depends on knowing the hydrogen, helium and heavy element content. But this model is in doubt because other solar physicists, using a different approach to studying the sun's interior, have not been able to detect a sufficient number of neutrinos, massless elementary particles, that should be produced by the sun's burning core (SN: 6/30/79, p. 420; 2/17/79, p. 103). To explain the lower neutrino count, the theorists may have to assume there is less helium in the sun than supposed by the model. However, Christenson-Dalsgaard believes that Duvall and Harvey's data support the current model's higher helium abundance, in opposition to the neutrino evidence. Further study of the solar modes may help resolve this contradiction.

The solar oscillation data may also solve the riddle of the sun's rotating core, and whether or not Einstein's theory of general relativity will need revision if the core is found to be rapidly rotating. Physicists first suggested in the 1960s that the theory, which concerns the nature of gravity, might need to be revised. Robert F. Dicke of Princeton University and his colleague Carl Brans developed an alternate theory of gravity. They argued that the orbit of Mercury would be affected in a slight but measurable way, if the sun's core were rotating more rapidly than had been assumed when Einstein developed his theory. The core's rapid spinning should cause the sun to flatten out slightly, and the flattening's gravitational influence on Mercury's orbit could be measured. The magnitude of the gravitational effect should be different from what Einstein's theory predicted.

Since 1966, Hill and his colleagues have been trying to determine if a modification of general relativity is necessary by studying the sun's flattening and its oscillations. Hill's team recently published data concerning the long-period oscillations (20 minutes to one hour) in the January SOLAR PHYSICS and the Dec. 13 PHYSICS REVIEW LETTERS that Hill feels call general relativity into question. "These are gravity modes with periods that are large. This is information about the deep core," he says. The team has calculated that the sun's core rotates very rapidly, about once every four days. (The sun's surface rotation varies with position on the surface. It ranges from 27 to 35 days per rotation.)

Dicke, meanwhile, began to change his views around 1973. He now argues that the five-minute oscillations (not the longer-period oscillations of Hill) indicate the sun is rotating only about once every 12.5 days. Still other theorists have also come out with different interpretations of the data. Everyone working in the field contacted by SCIENCE NEWS agreed that no one agrees on how fast the sun's core is rotating. Dicke says, "Anything as fundamental as a [modification of relativity] requires a more strongly based set of measurements than what we have available."

Hill, by contrast, is optimistic that the available and soon-to-be-available data will lead to new developments in the field. He likens the state of helioseismology today to spectroscopy (the branch of physics that probes matter by observing the electromagnetic radiation it absorbs or gives off) in the 1940s. Spectroscopists then had "hundreds of [observations] and 10 models, but only one of those models will fit. This decade is going to be a really exciting one because we have a lot of observational data. The important thing is not whose model is correct, but that we are on the threshold of a new understanding about the sun." □