on the use of available balloon, rocket, and satellite data, led to the conclusion that the observed O_3 concentrations at mid-latitudes substantiate calculated densities up to 30 km but monotonically diverge above 35 km such that observed O_3 concentrations (from a broad class of experiments) fall 30 to 50 percent above calculated concentrations between 40 and 50 km (*8*).

Taken together, these results imply a serious discrepancy because (i) the relevant cross sections and reaction rate constants in Eq. 1 have been carefully studied and, except for the O_2 photolysis rate, J_{O_2}, are known to ± 10 percent or better; (ii) recent in situ measurements defining the penetration of solar radiation into the middle stratosphere have narrowed the uncertainty in J_{O_2} (*9*); and (iii) O_3 can be measured to an accuracy of ± 5 percent at these altitudes. If we hope to be able to predict changes in O_3 in the next century to an accuracy of 10 percent, we must be able to "predict" its present concentration with considerably better accuracy than that cited above, particularly in the photochemically controlled regime above 30 km.

With the experimental control and repeatability afforded by the reel-down system, we can now systematically examine each of the chlorine, nitrogen, and hydrogen rate-limiting steps in the catalytic destruction of O_3. An analysis of variance between O_3 and the rate-limiting radicals as well as the diurnal, latitudinal, and seasonal trends can be used to establish cause-and-effect relations within and between the chemical cycles, thus providing a significantly more rigorous test of the dominant catalytic mechanisms.

Note added in proof: The reel-down system was launched for the second time on 14 September 1984 from Palestine, Texas. Two vertical scans of 8 km each were executed, each exhibiting dynamic stability. That flight began a series of experiments investigating the free chlorine radical, ClO, which limits the rate of chlorine-catalyzed recombination of O_3 and atomic oxygen to form O_2.

J. G. ANDERSON
N. L. HAZEN
B. E. MCLAREN
S. P. ROWE
C. M. SCHILLER
M. J. SCHWAB
L. SOLOMON
E. E. THOMPSON
E. M. WEINSTOCK

Department of Chemistry and Center for Earth and Planetary Physics, Harvard University, Cambridge, Massachusetts 02138

References and Notes

1. World Meterological Office–National Aeronautics and Space Administration, *The Stratosphere 1981: Theory and Measurements* (WMO Global Ozone Research and Monitoring Project Report 11, World Meteorological Office, Geneva, 1982); *Causes and Effects of Changes in Stratospheric Ozone: Update 1983* (National Academy Press, Washington D.C., 1984); G. Brasseur and S. Solomon, *Aeronomy of the Middle Atmosphere* (Reidel, Dordrecht, 1984).
2. H. S. Johnston, in *Stratospheric Ozone and Man*, F. A. Bower and Richard B. Ward, Eds. (CRC Press, Boca Raton, Fla., 1982), chap. 4.
3. F. S. Rowland, and M. J. Molina, *Rev. Geophys. Space Phys.* **13**, 1 (1975); also see the entire two-volume series, *Stratospheric Ozone and Man*, F. A. Bower and R. B. Ward, Eds. (CRC Press, Boca Raton, Fla., 1982).
4. B. Bolen and R. B. Cook, Eds., *The Major Biochemical Cycles and Their Interactions*, (Scientific Committee on Problems of the Environment Publication 21, Wiley, New York, 1983).
5. N. L. Hazen and J. G. Anderson, paper presented at the American Institute of Aeronautics and Astronautics 22nd Aerospace Sciences Meeting, Reno, Nev., 9–12 January 1984.
6. J. G. Anderson, H. J. Grassl, R. E. Shetter, J. J. Margitan, *J. Geophys. Res.* **85**, 2869 (1980).
7. M. J. Prather provided the $O(^3P)$ profile calculated for the conditions of the flight, using the model that provided the calculations for the results reported in *Causes and Effects of Changes in Stratospheric Ozone: Update 1983* (National Academy Press, Washington, D.C., 1984).
8. See, for example, M. K. W. Ko and N. D. Sze, *Geophys. Res. Lett.* **10**, 341 (1983); P. J. Crutzen and V. Schmailzl, *Planet. Space Sci.* **31**, 1009 (1983).
9. G. P. Anderson and L. A. Hall, *J. Geophys. Res.* **88**, 6801 (1983).
10. Acknowledgments extend to a broad community: J. Blamont first used cables to tether balloons in the troposphere; F. Kaufman first suggested using cables in the stratosphere; and the Dupont Corporation developed Kevlar with a strength-to-weight ratio ten times that of steel. That development allowed us to take the approach described in this report. M. Titchener and K. Roney developed much of the hardware-software used in the data acquisition and reduction. T. Schiller and E. Dobbyn contributed to the fabrication of the flight electronics. Several members of the National Scientific Balloon Facility, R. Kubara, K. Hazelwood, A. Shipley, and G. Cole, made critical contributions during difficult periods. This research was funded by the National Aeronautics and Space Administration.

19 November 1984; accepted 19 March 1985

The Fajada Butte Solar Marker: A Reevaluation

Abstract. *Evaluation of the Fajada Butte solar marker in Chaco Canyon, New Mexico, on the basis of its ethnographic context and usefulness for confirmatory and anticipatory solar observations indicates that the site does not function as an accurate solar calendar (accurate in the context of the historic Puebloan culture). The site most likely served as a sun shrine rather than as a calendrical observing station. The interpretation of the site as marking the northern declinations of the lunar 18.6-year cycle is not supported by the ethnographic evidence nor can the site be used to anticipate accurately the year of the standstill.*

The interpretation of Fajada Butte solar marker as a "unique solar marking construct" (*1*) has generated a controversy about this site in Chaco Canyon, New Mexico (*2*). I here assess the functions of the site in the context of the historic Pueblo culture. Arguing by analogy, I assume that this astronomical tradition holds in its general character back to prehistoric times and the practices of the Anasazi (*3*) who needed to keep a ritual calendar 1100 years ago.

The common elements (*4*) in calendrical observations of the sun among the historic Pueblos are: (i) a special religious official, the Sun Priest, is invested with the responsibility of watching the sun; (ii) observations take place, often daily at sunrise, from within or close to the pueblo; (iii) the most common observational technique involves the use of horizon markers; (iv) the most important ceremonial times of year are the solstices, especially the winter solstice; and (v) the Sun Priest must be able to announce the coming of ritual dates and does so by anticipatory observations.

The daily rate at which the sun travels along its horizon arc varies during the year. At the solstices, the sun has no noticeable motion. To determine the solstices accurately requires observations before the solstice, while the sun is moving observable amounts along the horizon. Using only the eye and horizon features, I estimate that the minimum detectable solar motion is 4 arcmin under the best conditions, which occur a week before the solstice. In practice, the limit may be 8 arcmin. [The precision obtained at Hopi Walpi for the winter solstice ceremony was 10 arcmin (*5*)]. A Sun Priest can then tally days to predict the solstice (*6*). Puebloan precision for solstice prediction seems to be within 1 day in principle and no more than 2 days in practice (*4*).

This concept of anticipation can be applied to the three rock slabs and petroglyphs that make up the Fajada Butte solar marker, which rests on the east side very near the top of the butte. To reach the site, one climbs the talus slope around the butte and up through a narrow rock chimney, passing enroute two archeological sites, 29 SJ 296 and 29 SJ 297. Site 297 lies closest to the solar marker; it has Mesa Verdan cultural characteristics. The National Park Service survey of site 297 in 1972 included the two petroglyphs that make up the "solstice marker" or "sun dagger" site as well. (It has since been designated 29 SJ 2387). One petroglyph is a spiral some

40 cm in diameter with 19 turns; to the left and somewhat above it lies a 10-cm spiral with a tail, probably a snake figure.

Sofaer *et al.* (*1, 2*) describe the play of light and shadow across the glyphs that is caused by the openings between the slabs and proposed that the precision of the calendrical cycle displayed implies purposeful use of the site by the Anasazi. Sofaer *et al.* (*1*) claim that the site "achieves its results with an accuracy comparable to that of the large monuments and structures of other ancient cultures," without specifying which constructions of which cultures. [Newman *et al.* (*7*) presented evidence that the three-slab site is probably a natural rockfall rather than an Anasazi construction.] I argue here that the predictive accuracy of the Fajada marker is inferior to that obtained by the historic Pueblo Sun Priest using horizon watching.

To evaluate the site requires a close look at its usefulness for anticipation of the solstices. The crucial seasonal change is the horizontal motion of the rightmost light shaft, which reflects the seasonal change in the sun's declination. The total shift across the spiral petroglyph of the right-hand light shaft from summer to winter solstice is about 18 cm. One month before the summer solstice, the shaft lies 3.2 cm to the right of the center of the spiral so that its leftward motion averages 1.1 mm per day. This rate slows down considerably as the time approaches the summer solstice; Sofaer *et al.* (*1*) note that at the solstice, the shaft moves only 2 mm in 4 days.

Given the width of the light shaft (about 2 cm) and the rough weathered appearance of the spiral, I judge that horizontal shifts of 1 mm per day are not, in practice, reliably marked—especially when the moment used to mark the timing is not known. Furthermore, it is not clear what part of the light shaft was used or can be used to watch for a consistent indicator. Thus, although the site is visually appealing, with the solstices and equinoxes marked by different configurations of light, the "sun dagger" site cannot be used in practice with the same predictive accuracy for the solstices as achieved by sun priests for the historic Pueblos (1 to 2 days).

If the Fajada site was used by the Chacoan Anasazi, what was its purpose? The historic Pueblos clearly distinguish sun-watching places, used for calendrical purposes, from sun shrines, used for the deposition of offerings (such as prayer sticks). Sun-watching stations usually are located within or fairly close to the pueblo, since a Sun Priest often makes observations daily. They are not usually marked in a noticeable way (if at all): the place may be the roof of a clan house at Walpi (*8*), a plain slab of rock on the ground, as at Zia (*9*), or a location in front of the church, as at Acoma (*10*). Sun shrines, usually located away from the pueblo, are commonly marked by piles of rocks or rock slabs (*11, 12*) and can be found on the tops of mesas at places marking important places for viewing sunrises and sunsets (*13*); they may be marked by petroglyphs or other rock art. The Fajada site appears to fit the characteristics of a shrine more closely than it does those for calendrical sun-watching stations. If the site was a shrine, a Sun Priest would make seasonal, but not daily, journeys to the butte to pray and deposit offerings at dawn (*14*). The site would act as a hierophany (a sacred showing of the sun) rather than an accurate calendar.

Sofaer *et al.* (*2*) also argue that the rock slabs and large spiral serve as a marker for the 18.6-year lunar standstill cycle. The gist of their inference is as follows: at moonrise (as well as sunrise), the edge of the easternmost slab casts a shadow on the large spiral. At a declination of 0°, the shadow falls to the right of the spiral; at 18.4° (minor standstill), the shadow cuts through the center; and at 28.7° (major standstill), the shadow strikes the left edge. The lunar standstill cycle can be considered in analogy to the sun's seasonal cycle. It takes the moon 9.3 years to vary from the smallest angle (minor standstill, about 18.5°) to the largest (major standstill, about 28.5°). The total cycle takes 18.61 years. During the standstills, the moon's greatest declination during a month does not change much so that the moon "stands still" as does the sun at solstices.

The functioning of the site for standstills is quite limited. First, it "works" only for the northern declinations of the sun and moon; the southerly ones are excluded by the rocks' orientation. Second, it will function only at moonrise, restricting its possible use to phases from a day or two past full moon to a few days after last quarter. The selective observations that can be made limit the usefulness of the site for observing the standstill cycle (*15*). As an example, consider 1969 (the year of the last major standstill) and the 3 years following. Assume that the site works effectively for phases from the full moon to the last quarter. Then from 1969 to 1972, only 25 percent of the northern extremes would be marked by the site, if the weather was clear during all of the suitable times, an unlikely condition.

Another limitation is that the site cannot be used to anticipate the year of the major or minor lunar standstill with an accuracy of 1 year because, as is the case for the solstice, the rate of change of the declination is very small. The best anticipatory observation can be made when the moon's declination is changing most rapidly at times midway between standstills. For example, in 1982 the maximum monthly declination increased from 21.85° to 23.55°. On the basis of site measurements (*16*), this angular change shifts the moonrise shadow by 3 cm in a year, an observable amount. During the year of the major standstill, the moon's declination changes only 45 arcmin. That amounts to a linear change on the rock face of 0.8 cm in the year or 6 mm in a month; these differences would be hard to discern on the weathered petroglyph, especially in moonlight. For a period of 2 years, the linear motion is about 1.5 cm after the major standstill; for 3 years, a little over 2 cm. Hence at major standstill, the shadow motion over many months is not easy to observe.

No evidence indicates that the historic Pueblos had any notion of or interest in the 18.6-year lunar cycle. Their interest apparently relates to phases of the moon to subdivide the year into months (*8, 17*), its position in the sky as a timing device (*8*), and lunar eclipses (*8, 18, 19*).

I conclude with an interpretation of the shadow markings at the Fajada site that is more consistent with the ethnographic evidence than that of Sofaer *et al.* (*1, 2*). Sun shrines and sun-watching stations are most often used at sunrise. Consider, then, the sun's shadow rather than the moon's. It tracks out the solar declinations from spring equinox to the summer solstice, the period spanning planting season in a place like Chaco Canyon. The turns in the spiral could then mark out a rough planting calendar. Also, the shadow cuts the center of the spiral at a declination of 18.6°, which occurs in the middle of May, a date not considered significant by Sofaer *et al.* (*2*). Yet, at Hopi at this time, important corn and bean planting is carried out (*17*). In addition, a May date may help in anticipating the summer solstice. The shadow passing through the spiral's center and a date tally could predict the summer solstice with much better accuracy than the late morning light shafts. In mid-May, the sun's azimuthal speed is about 19 arcmin per day. This translates into a linear motion of 2.5 mm per day on the spiral. Hence, the sunrise light would make a better calendrical marker than the midmorning shafts, but not much better.

MICHAEL ZEILIK
Department of Physics and Astronomy, University of New Mexico, Albuquerque 87131

References and Notes

1. A. Sofaer, V. Zinser, R. M. Sinclair, *Science* **206**, 283 (1979).
2. A. Sofaer, R. M. Sinclair, L. E. Doggett, in *Archaeoastronomy in the New World*, A. F. Aveni, Ed. (Cambridge Univ. Press, Cambridge, 1982), pp. 169–181.
3. F. H. Ellis, in *Archaeoastronomy in Precolumbian America*, A. F. Aveni, Ed. (Univ. of Texas Press, Austin, 1975), pp. 59–87.
4. M. Zeilik, "Anticipation in Anasazi astronomy," paper presented at the 56th Annual Pecos Conference, Bluff, Utah, 11–13 August 1983; "Historic Puebloan sun watching," paper presented at the First International Ethnoastronomy Conference, Washington, D.C., 5–9 September 1983; "Anticipation in ceremony: The readiness is all," paper presented at the Symposium on Astronomy and Ceremony in the Prehistoric Southwest, Maxwell Museum, University of New Mexico, Albuquerque, 12–14 October 1983).
5. S. C. McCluskey, in *Archaeoastronomy in the New World*, A. F. Aveni, Ed. (Cambridge Univ. Press, Cambridge, 1982), pp. 31–57.
6. C. D. Forde, *Habitat, Economy, and Society* (Dutton, New York, 1934), pp. 226–227.
7. E. B. Newman, R. K. Mark, R. G. Vivian, *Science* **217**, 1036 (1982).
8. A. M. Stephen, *Hopi Journal*, E. C. Parsons, Ed. (Columbia Univ. Press, New York, 1936).
9. L. A. White, *Bur. Am. Ethnol. Bull.* **184** (1962).
10. ———, *Bur. Am. Ethnol. Annu. Rep.* **47**, 17 (1932).
11. M. C. Stevenson, *ibid.* **23**, 42 (1904), figure 2.
12. J. W. Fewkes, *Am. Anthropol.* **8**, 346 (1906), plate xxviie.
13. M. Titiev, *Mus. Notes Mus. North. Ariz.* **11**, 39 (1938).
14. J. W. Fewkes, *J. Am. Ethnol. Archaeol.* **2**, 1 (1892).
15. E. Ellegard, *Curr. Anthropol.* **22**, 99 (1981).
16. R. M. Sinclair, private communication.
17. E. Beaglehole, *Yale Univ. Publ. Anthropol.* **15** (1937).
18. E. C. Parsons, *Bur. Am. Ethnol. Annu. Rep.* **47**, 193 (1932).
19. ———, *General Series in Anthropol.* **2** (1936).

27 July 1984; accepted 17 April 1985

Microinjected c-*myc* as a Competence Factor

Abstract. *While a number of oncogenes are expressed in a cell cycle–dependent manner, their role in the control of cell proliferation can only be established by a direct functional assay. The* c-myc *protein, upon microinjection into nuclei of quiescent Swiss 3T3 cells, cooperated with platelet-poor plasma in the stimulation of cellular DNA synthesis. This suggests that* c-myc *protein, like platelet-derived growth factor (PDGF), may act as a competence factor in the cell cycle to promote the progression of cells to S phase. The presence in the medium of an antibody against PDGF abolished DNA synthesis induced by microinjected PDGF; however, the microinjected* c-myc *protein stimulated DNA synthesis even when its own antibody was present in the medium. The* c-myc *protein may act as an intracellular competence factor, while PDGF expresses its biological activity only from outside the cells.*

Microinjection of the cloned Harvey *ras* gene or the $p21^{v\text{-}ras}$ protein induces cellular DNA synthesis in quiescent mammalian cells (*1, 2*). In contrast, microinjection of a cloned v-*myc* gene (*2*) or of the c-*myc* protein, under the same conditions as those used for the Harvey *ras* gene or protein, fails to induce cellular DNA synthesis in quiescent cells. Nevertheless, a role of c-*myc* in the control of cell proliferation is suggested by several findings including the following: (i) c-*myc* expression is induced by growth factors and mitogens (*3*); (ii) regulation of expression of c-*myc* is altered in chemically transformed mouse cells (*4*); (iii) DNA synthesis occurs when a c-*myc* gene (placed under the control of the mouse mammary tumor virus promoter) is introduced into 3T3 cells in the presence of glucocorticoids (*5*); and (iv) c-*myc* expression is altered in certain forms of neoplasia (*6*).

We now show that microinjected c-*myc* protein induces DNA synthesis in quiescent 3T3 cells if the cells are exposed to platelet-poor plasma (PPP) after microinjection. In the competence-progression model (*7*) c-*myc* can, therefore, be classified as a competence factor. This model is based on the observation that platelet-derived growth factor (PDGF), by itself, cannot stimulate DNA synthesis in quiescent BALB/c 3T3 cells. However, DNA synthesis occurs if cells are treated with PPP after exposure to PDGF. PPP, by itself, has no effect. PDGF makes the cells "competent" (competence factor), and PPP allows their progression into S phase (progression factor).

The purified c-*myc* protein was obtained by recombinant DNA technology as described (*8*). It is recognized by antibodies raised against specific c-*myc* peptides, and, when microinjected into the cytoplasm of cells, rapidly migrates to the nucleus (*9*). In the experiments described below, the c-*myc* protein was microinjected into the nuclei of quiescent cells by means of the manual technique of Graessmann and Graessmann (*10*). For microinjection, the c-*myc* protein and the control protein (albumin) were dissolved in phosphate-buffered saline (PBS) lacking Ca^{2+} and Mg^{2+}, since these two ions can be considered as competence factors. PPP was prepared as described (*11*) from human plasma after removal of platelets and chromatography on CM-cellulose.

Swiss 3T3 cells were plated on glass cover slips in 60-mm petri dishes at a concentration of 5×10^4 per dish in 10 percent fetal calf serum. After 3 days of incubation, the serum concentration was reduced to 1 percent calf serum and incubation continued for 3 to 4 days. At this time, the cells were quiescent and could be used for microinjection. The cells in a circle delimited by etching were microinjected, while the cells outside the circle were used as uninjected controls (Fig. 1). Several experiments were carried out in a similar way with c-*myc* protein or bovine serum albumin, with or without PPP (Fig. 2). Microinjection of the c-*myc* protein (not followed by PPP) caused a small increase in the percentage of cells labeled by $[^3H]$thymidine; an average of 3.9 percent were labeled in the microinjected group as compared to an average of 1.4 percent in the uninjected cells. The significance of this increase is questionable, not only statistically but also biologically. In six separate experiments, in which the cells were treated with PPP (5 percent) after microinjection, c-*myc* protein caused a marked increase in the percentage of cells entering S phase. The average percentage of cells in S phase was 19.7 (range, 10.5 to 30.0 percent) in microinjected cells as compared to an average of 1.5 percent (range, 0.6 to 4.9 percent) in controls. The extent of stimulation is considerable, since, under these conditions (labeling for 24 to 28 hours), serum stimulation of quiescent cells results in the labeling of only about 40 percent of the cells. The possibility that a combination of microinjection and PPP could result in the stimulation of celluar DNA synthesis is ruled out by the experiments in Fig. 2, where c-*myc* protein was replaced by bovine serum albumin. An average of 3.7 percent of cells microinjected with albumin were labeled by $[^3H]$thymidine as compared to 2.1 percent of control cells. We have microinjected a great number of proteins into quiescent 3T3 cells. None stimulated, except c-*ras* (*2*) and the SV40 large T antigen, both of which stimulate cell DNA synthesis even in the absence of PPP.

Our results suggest that c-*myc* is a competence factor, in the competence-