layer of volcanic ash, caused the prehistoric tundra at Miller Creek to be buried, in spring or early summer when the vegetation layer was still frozen. This would have smothered the inhabitants of the burrow, and prevented the soil around it from thawing; also, it would have caused the permafrost level to rise, thereby assuring that the lupine seed would remain dry and continually frozen.

Ødum (*10*) has reported that in archeologically dated sites in Denmark, under optimal conditions of moisture and oxygen deficiency, seed of a large number of common weeds may remain viable for many centuries, and that seed of *Chenopodium album* and *Spergula arvensis* germinated after remaining dormant for 1700 years. The previous record for seed longevity, however, is probably that of the sacred lotus (*Nelumbium nuciferum*) dormant for 2000 years in a far-Eastern peat bog (*11*). If, under suitable conditions, seed have survived in unfrozen soil for so long, it would seem reasonable to predict that seed stored dry and at temperatures well below freezing, could remain viable indefinitely.

Rorippa barbareaefolia, aberrant from other members of the genus by its four-valved pods, together with *Descurainia sophioides* and *Senecio congestus*, are so common on fresh, water-deposited tailings in the placer mining districts of Alaska and Yukon that sourdough miners firmly believe that these plants grew from seed dormant in the frozen muck brought to the surface by placer mining operations. A more likely explanation is that all three are pioneer species on freshly disturbed soil (*12*). Whereas *Descurainia sophioides* and *Senecio congestus* are widespread and ubiquitous throughout northern and central Alaska and Yukon, *Rorippa barbareaefolia* apparently is restricted to the placer mining districts where its rather erratic and sporadic occurrence might suggest the occasional release of seed from once-frozen silts of Pleistocene age (*13*).

The frozen muck deposits of unglaciated Alaska have yielded a variety of plant remains, including diaspores (*2*). With the technique described by Ødum (*10*) it might well be worth testing carefully selected and dated cores from muck deposits to see if viable plant seed or spores might not occur in them.

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3 August 1967

Rotation of Venus: Continuing Contradictions

Abstract. *Optical observations of Venus have yielded various values of the rotation period extending from less than one to several hundred days. Radar observations give a retrograde rotation of the solid globe in 244 ± 2 days. Recent ultraviolet photographs, however, show relatively rapid displacements of clouds in the high atmosphere of Venus which suggest a retrogrode rotation in only 5 days. The two rates seem to be physically incompatible.*

The history of reported determinations of the rotation period of Venus has been cluttered with inconsistencies and contradictions. Optical observations of the cloud-covered planet have led various observers to report values ranging from less than one day to several hundred, including the so-called "synchronous" period of 225 days which is equal to one orbital revolution (*1*). In general, very little observational evidence has been produced to substantiate any of these various divergent results; but, in 1956, high-dispersion spectra obtained by Richardson (*2*) showed small Doppler displacements corresponding to a retrograde rotation with a period of 14 days. Richardson's probable error, unfortunately, was as large as the observed rotation and little attention was given to his results. Ironically, spectroscopic measures by Slipher (*3*) in 1903 and St. John and Nicholson (*4*) in 1923 also indicated retrograde rotation, but the results were discounted because they felt it unlikely that Venus would rotate in the opposite direction to the earth and Mars.

Radar measurements of the rotation of Venus were introduced in 1961 with the announcement that "the planet rotates very slowly" (*5*). Other radar Doppler observations made in 1961 suggested that the rotation was retrograde (*6*) and a few years later the rotation was reported to be definitely retrograde with a period 250 ± 40 days about an axis approximately normal to the ecliptic (*7*). Recently Dyce and Pettengill (*8*), using the frequency dispersion of time-gated radar echos, have given the rotation period as 244.3 ± 2 days retrograde, with the axis of rotation inclined $-89°.1 \pm 1°$ to the ecliptic. It would seem as though the question of the rotation of Venus had finally been settled by radar.

Photographically, Venus is nearly featureless throughout most of the visible spectrum. In blue light, however, dusky shadings are noticeable, while in ultraviolet light, where we are presumably viewing the upper levels of the planet's atmosphere, these irregular markings are more enhanced and become the characteristic features of the photographic image. Last year, observers at the French high-altitude observatory at Pic-du-Midi obtained several sequences of ultraviolet photographs, with intervals varying between 2 and 6 hours, during which the markings were observed to move. Measurements of the motions of these ultraviolet "clouds" as they moved away from the sunrise terminator (the line on the planet separating sunlight and darkness) suggested a retrograde rotation period of approximately 4 days (*9*).

Subsequently, photographs taken in June and July 1966 at the New Mexico State University Observatory confirmed the cloud motions reported by the French astronomers. Throughout 1966, however, only the region near the morning terminator of Venus could be observed, and it was quickly noted that the observed cloud motions could just as readily be explained by

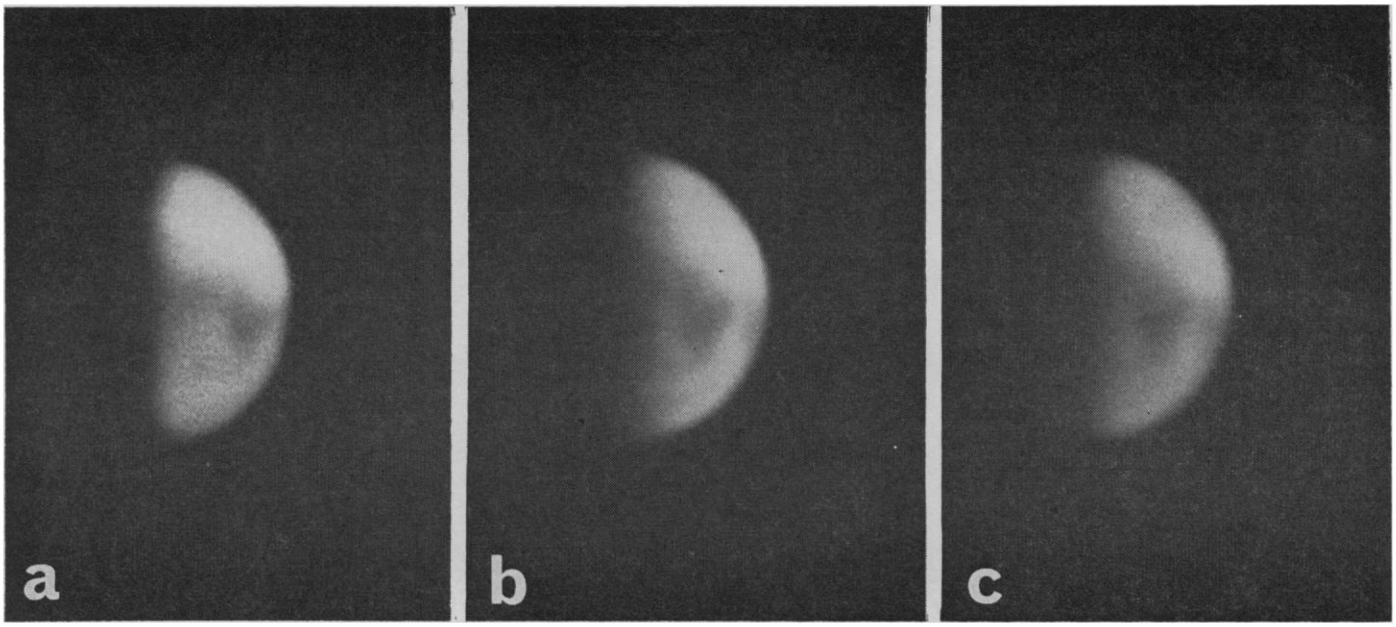

Fig. 1. Ultraviolet photographs of Venus taken at (a) 2230 hours, 7 June 1967; (b) 0206 hours, 8 June 1967; and (c) 0311 hours, 8 June 1967. North is at the top. All times given are Universal Time. Note the right to left (retrograde) drift of the dark wedge-shaped cloud during the 4.7-hour interval.

a general high-level wind blowing toward the subsolar point.

Throughout May and June of this year the evening terminator was turned toward the earth and a number of series of ultraviolet images of Venus were obtained by T. Pope and A. Murrell, using the new 61-cm reflector at the New Mexico State University Observatory. The unusual quality of these photographic images allowed several well-defined features to be measured on many of the series, with intervals extending from 1.9 to 4.7 hours. From the most casual examination it was immediately evident that the motion of the clouds was toward the evening terminator, *away* from the subsolar point, and that retrograde motion was being observed in the high-level ultraviolet clouds. Moreover, the same general motion was observed in several clouds distributed over the visible disk. The displacement rates of the clouds varied only slightly from day to day, and if it were to be assumed that their motion is generally unchanging around the circumference of the planet, these observed displacements would give rise to a mean rotation rate of somewhat less than 5 days with an uncertainty of about ¼ day (*10*).

Although the cloud motion was generally toward the terminator, we did find a small component in a direction parallel to the terminator, which at this time was approximately normal to the orbital plane. The average value of this component was about twice that of the mean measuring error. Now, from our measures alone, we cannot be certain that a unique rotation axis exists for these high-atmosphere clouds. If, however, we choose to interpret the observed cloud motions in the belief that a unique axis does exist, we would infer that the projected inclination of this axis to the axis of the orbit was approximately 4° at the time of our observations. The true orientation of such an axis could be established only through additional observations of Venus at widely spaced geocentric ecliptic longitudes.

New observations and refined measures of a larger number of discrete points would probably reduce the uncertainties in the velocities of the ultraviolet clouds; but the question of whether or not these velocities are maintained as the clouds continue around the planet cannot be answered. We simply cannot see all of Venus at any one time.

It would then be reasonable to ask whether or not individual cloud patterns can be recognized over intervals of 4 or 5 days. As early as 1957, Ch. Boyer reported to the (French) Academie des Sciences that he had observed repetitive patterns at 4-day intervals. These results were reaffirmed in a series of publications (*11*) over the past 6 years. A similar investigation of a large number of our own photographs taken since 1959 has failed to reveal any *well-defined* repetitive patterns, although somewhat similar formations often reoccur at 3- to 5-day intervals. Among the high-resolution photographs taken this year, however, there is one pair of plates taken 5.0 days apart in which the cloud formations are remarkably similar. Yet, other pairs of plates selected at 4- or 5-day intervals may show little or no resemblance whatsoever; and this is to be expected when contending with atmospheric phenomena. We do not know the lifetimes of cloud formations on Venus.

Studies of the lifetimes of individual clouds are hampered by the relatively short interval in each day during which any single observatory can observe Venus and by the correspondingly rapid displacement of a given cloud from the center of the apparent disk of the planet, thereby making it unlikely that the same cloud would be reobserved after an interval of 20 hours or so. Because of the uncertainties in the lifetimes of Venus cloud formations, there is no assurance that similar patterns reappearing after 4 or 5 days are in fact the original clouds. Unknown processes originating deeper within the atmosphere or on the solid surface itself could be instrumental in determining the macroscopic cloud structure at the observed upper levels. Therefore, the periodicity with which a given pattern reappears may be completely unrelated to the apparent rotation period of the high-level clouds. Indeed, some of our 1967 plates show strikingly similar cloud patterns at intervals of only 2 days, although the individual cloud displacements during several hours on these same dates clearly exhibit motions corresponding to a rotation period of about 5 days (Fig. 1).

The greatly different rotation periods of Venus as determined by both optical and radar observations are difficult to reconcile with one another, for such would require a persistent and widespread planetary wind system having speeds in excess of 300 km/hr with respect to the solid surface; and although the terrestrial jet stream will attain these speeds, it is basically a narrowly confined zonal wind and, therefore, quite different from that observed on Venus. We are, unhappily, confronted with two rather widely divergent rotation periods for the atmosphere of Venus and its solid surface, 5 days and 244 days, respectively. The study of the rotation of Venus continues to produce inconsistencies.

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Local Geomagnetic Events Associated with Displacements on the San Andreas Fault

Abstract. *The piezomagnetic properties of rock suggest that a change in subsurface stress will manifest itself as a change in the magnetic susceptibility and remanent magnetization and hence the local geomagnetic field. A differential array of magnetometers has been operating since late 1965 on the San Andreas fault in the search for piezomagnetic signals under conditions involving active fault stress. Local changes in the geomagnetic field have been observed near Hollister, California, some tens of hours preceding the onset of abrupt creep displacement on the San Andreas fault.*

The magnetic properties of rocks are sufficiently dependent on stress to suggest that geomagnetic observations could be used to remotely monitor changes in tectonic stress; this method would complement other techniques under investigation in the field of earthquake prediction. This stress-dependent behavior is known as inverse magnetostriction or piezomagnetism and is the consequence of the magnetocrystalline anisotropy of the magnetic minerals, chiefly magnetite, which are present in the rocks.

The magnetic susceptibility and remanent magnetization change with applied compressive stress (*1*). In common igneous rocks the susceptibility parallel to the axis of compression decreases by about 2 percent for an applied stress of 100 bars. The susceptibility at right angles to this applied stress is enhanced by a slightly greater amount (Fig. 1).

The geomagnetic field intensity observed on the surface is a function of the susceptibility and remanent magnetization of the subsurface rocks in the immediate vicinity to the depth of the Curie point isotherm. A change in the subsurface stress should, therefore, by virtue of the piezomagnetic effect cause a change in the observed field intensity. Possible piezomagnetic effects associated with the stress variations of local earth quakes have been reported (*2*) but these observations lacked the repetition and rigorous experimental arrangements necessary to firmly establish their validity.

In order to search for piezomagnetic effects in a seismically active zone, an array of optically pumped rubidium vapor magnetometers (*3*) was established on the San Andreas fault in central California in August 1965 (Fig. 2). The experiment was directed towards recognizing a local change in the geomagnetic field and determining what relationship exists, if any, between such events and seismic or strain events. The magnitude of any observed piezomagnetic effect is determined by the magnitude of the stress change, the unstressed value and stress dependence of the susceptibility, and the usual factors defining a magnetic anomaly. Since the time variation of stress changes in a seismically active area is unknown and the estimated magnitude of the piezomagnetic effect is small

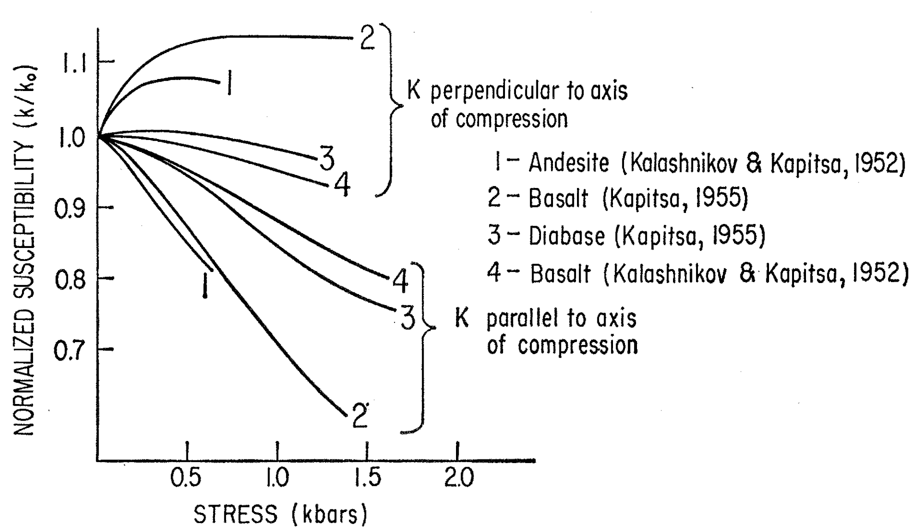

Fig. 1. Experimental data on the variation of magnetic susceptibility of common rocks with applied stress. The susceptibility parallel to the axis of compression decreases with the applied stress whereas the susceptibility perpendicular to the axis of compression is usually initially enhanced. Susceptibility is normalized to susceptibility at zero pressure.