Creek, Oregon, produced C^{14} dates of 7010 ± 120 (GaK-1124, unpublished data) and 6940 ± 120 [Tx-487, *Radiocarbon* **10**, 389 (1968)]. These are the most reliable dates, so far, for the major eruption of Mount Mazama.
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8. Thin sections were ground to a thickness of 0.05 to 0.10 mm by means of a slurry of size-600 abrasive powder and water. Measurements were made at 600 magnifications under normal light with a Vickers–A.E.I. image-splitting eyepiece. The manufacturer claims that the Vickers eyepiece is accurate to 0.1 μ, which is therefore the theoretical precision limit for any set of measurements made with this particular device. Claims of a better precision cannot be substantiated.
9. The results of the C^{14} age determinations are given as "radiocarbon years" to distinguish them from calendric years, which they are not. Conversion to calendric time is still an uncertain, complex process and for that reason it is not attempted here. Factors which would have to be taken into account are the new C^{14} half-life and the production rate of C^{14} by cosmic rays. See M. Stuiver and H. E. Suess, *Radiocarbon* **8**, 534 (1966); P. E. Damon, A. Long, D. C. Grey, *J. Geophys. Res.* **71**, 1055 (1966).
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Polar Temperature of Venus

Abstract. *The presence of substantial polar cooling of Venus, as derived from microwave interferometry at 10.6 cm wavelength, is shown to be open to doubt. Other microwave measurements give little evidence for significant poleward variation in temperature on the planet.*

Earth-based microwave measurements of the polar temperature of Venus at 10.6 cm (*1*) have been thought to show the presence of substantial polar cooling on Venus, with the poles approximately 25 percent cooler than the equator. Such cooling would be very significant in consideration of Venus's meteorology and biogenic capability, and the measurements have been used to support the hypothesis of ice caps on the planet (*2*).

However, reexamination of the interferometric data at 10.6 cm, from which the cooling was primarily deduced, indicates that a systematic error was present. Polarization measurements at the same frequency show some evidence for polar cooling, with magnitude 23 percent (*3*), but the measurement is uncertain.

A recent interferometric study at 3.12 cm (*4*) has shown no significant departure from a circularly symmetrical distribution for the observed disk brightness. The high atmospheric opacity at this wavelength implies, however, that the surface temperature was not directly measured.

The 10.6-cm interferometric study of Venus's polar cooling was made during the period of the inferior conjunction of 1964. The technique has been described (*5*), and we need note here only that at each instant a microwave interferometer gives an output, termed the fringe visibility, which is the instantaneous sample of the Fourier transform of the source brightness. The sampling point is determined by the length and orientation of the interferometer base line, the line joining the two telescopes which comprise the interferometer, as viewed foreshortened from the source. Figure 1 shows how the projected base line varies as the earth rotates during the day, with time measured by the hour angle of the source. We have chosen the latitude of the interferometer (37°) and the declination of the source (20°) as those which obtained during the 10.6-cm observations of Venus.

For a planet with polar cooling, in contrast to circularly symmetric brightness distribution, the fringe visibility is dependent on the base line orientation. The magnitude of the cooling may be derived from the difference in fringe visibilities for base lines with the same projected length, but with differing position angles with respect to the pole. For base lines with the same inclination with respect to the pole, and with the same projected length, there will be no difference in fringe visibility, regardless of the form or amount of polar cooling.

The observations of Clark and Kuz'min extended from 25 May to 18 July 1964. During the period 4 to 10 June, the position angle γ of the Venus pole was less than 1°, as now known from radar measurements of the pole position (*6*). The projected east-west base line was then equally inclined to the pole of Venus for the two times at equal hours before and after meridian transit. This can be seen by reference to Fig. 1, which shows base lines for $+4^h$ and -4^h. Since the lengths of the projected base lines were equal for these two times, the visibilities measured—$F_<$ for the time before meridian transit and $F_>$ for the time after meridian transit—should have been the same, as discussed above.

Figure 2 shows the results obtained by Clark and Kuz'min, together with the curve predicted with the use of a model (*7*) with no polar cooling. It can be seen from Fig. 2 that from 4 to 10 June, the measured $F_<$ (filled circles) was consistently smaller than $F_>$ (open circles). For $\beta = 0.438$ this difference was five times the random error from noise.

If the effect is real, it would indicate an extraordinarily large temperature gradient across the planet with the cold points strongly displaced from the poles of Venus. With a displacement of 45° in position angle, giving the smallest gradient for a given difference in $F_> - F_<$, the cold point would have to be at a temperature some 500°K cooler than the average temperature. Such an asymmetric cooling is unlikely on physical grounds, because it is known from the radar results that for Venus the orbital plane and the equator are inclined by only 1.2°, while the dense atmosphere of Venus is unlikely to sustain the large thermal gradients described.

It is more probable that the difference was due to a systematic error. The error may possibly be explained as arising from an error in telescope pointing for easterly hour angles $H < 0$, greatest when the source had just appeared above the horizon (*8*).

From the differences $F_> - F_<$ the data of 27 to 30 June and 10 to 13 July indicate some polar cooling, but a similar systematic error cannot be excluded. We therefore conclude that the 10.6-cm measurements give no reliable interferometric evidence for polar cooling on Venus.

Observations at 3.12 cm have been made by Berge and Greisen (*4*). Their measurements were made at base lines such that the projected length was constant, while their inclinations from Venus's north pole were either 20° or 70°. The difference in fringe visibilities ΔF under these conditions was

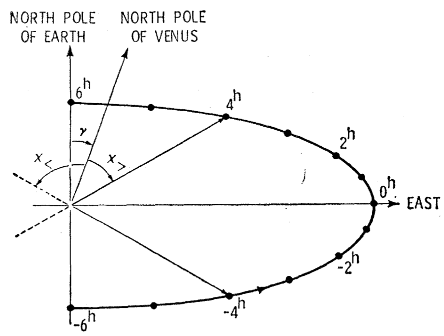

Fig. 1. Variation of the projected interferometer base line as the earth rotates during the day. When γ is small, the inclination angles $\chi_>$ and $\chi_<$, shown here for base lines at hour angles of $\pm$ 4h, are almost equal.

measured to be $(-3.6 \pm 5.0) \times 10^{-3}$, which implies a small polar heating with magnitude $\sim 2.0 \pm 2.8$ percent of the average surface temperature. In view of the experimental error the apparent heating is not statistically significant.

The total optical depth of the Venus atmosphere is large at 3.12 cm, being 1.8 for the model described by Gale *et al.* (*7*). The atmosphere thus both strongly emits radiation itself and attenuates the radiation from the surface. It is primarily the distribution of atmospheric absorptivity and temperature which is measured, and the surface temperature distribution is only important as it affects the atmospheric distribution. Thus we would place a limit of 3 percent on the polar cooling of the atmosphere seen at 3.12 cm. In view of the very sensitive temperature and pressure dependence of the absorptivities of the known constituents of Venus's atmosphere (*9*), the question of polar cooling of the surface must remain open.

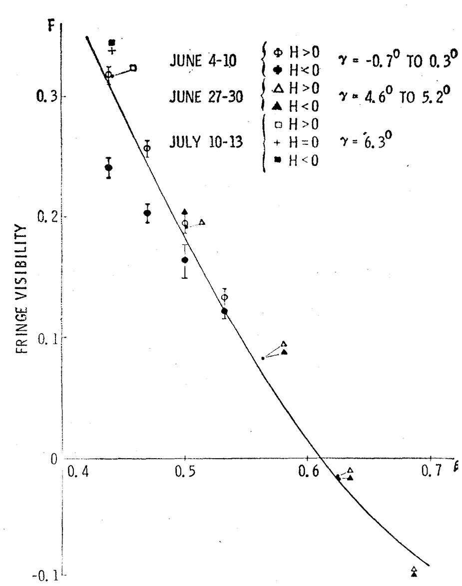

Fig. 2. Venus's fringe visibility $F(\beta)$ at 10.6 cm; β is the length of the base line, in wavelengths, multiplied by the planetary radius. The points show the observations, together with root-mean-square error bars for the data of 4 to 10 June 1964. The filled circles are believed to be in error. F for a uniform temperature planet is given by the solid curve.

A second technique for determining the polar cooling requires measurement of the integrated polarization of the radiation from the planet. The electromagnetic radiation from a given surface element of a planet will be partially linearly polarized (*10*). For a given polarization, maximum emission occurs at two points near the edge of the planet's disk, on the diameter defined by the polarization direction. If the planet is at a uniform temperature, these "Brewster angle" highlights will have a constant intensity for all choices of polarization direction, so that the integrated emission from the planet has no net polarization. With polar cooling, however, the highlights for polarization in the direction of the axis will be cooler than those for polarization in the direction of the equator. Thus, there will be a net polarization in the direction of the equator.

At 10.6-cm wavelength and for short interferometric base lines, so that the measurement was effectively that for a single telescope, Clark and Kuz'min (*1*) found the net polarization $p = 0.8 \pm 0.5$ percent at an angle $20° \pm 20°$ from the equator. For our atmospheric model, this implies a polar cooling of 23 ± 14 percent.

At 6-cm wavelength, Dickel (*11*) found $p = 0.5 \pm 0.9$ percent in the direction of the poles. The equatorially directed polarization expected on the basis of the model with 23 percent polar cooling is 0.3 percent, one-third of the stated error. It is apparent that the net polarization at 6 cm has not been detected.

It appears that present knowledge of the polar temperature of Venus's surface is very limited. While the 3.12-cm results have clearly shown that the poleward temperature variation of the atmosphere observed at this wavelength is small, only long wavelength radiation can penetrate the atmosphere, and measurements in this region are uncertain. However, it can be expected that interferometric measurements made during the 1969 inferior conjunction with the considerably improved accuracy now available, will determine the polar surface temperature within narrow limits.

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Red Sea Floor Origin: Rare-Earth Evidence

Abstract. *Abundance patterns of rare earths of submarine tholeiitic basalts from the axial trough of the Red Sea resemble those of basalts from mid-ocean ridges but are distinct from shield or plateau basalts of tholeiitic composition. These results imply that a similar magmatic process, related to spreading of sea floors, operates beneath the axial trough of the Red Sea and the crest of mid-ocean ridges.*

Seismic, gravity, magnetic, and heat-flow studies (*1*) of the Red Sea have led several workers to postulate that this area is a locus of ocean-floor spreading (*2, 3*). If this is true, the axial trough may be analogous to the central part of a mid-oceanic ridge, and the associated submarine basalts similar to those extruded on a mid-oceanic ridge.

To test this possibility, Chase (*4*) investigated the petrochemical characteristics of basaltic fragments raised in cores from the axial trough of the Red Sea between 19° and 23°N. These re-