events will result in a higher equilibrium velocity and, probably, counterflow. Containment of flow within a zone can be maintained by a pressure discontinuity lateral to the flow.

The several climatic implications of this possible mechanism include a migration of the jet stream to higher latitudes, in the case of a generally cooler or more carbonic atmosphere, and to lower latitudes with a warmer or moister atmosphere. The position is insensitive to moderate changes in the composition of the atmosphere, and to atmospheric pressure.

At the equator, the heat pulse travels through the atmosphere at Mach 1 only at very high altitudes (about 150 km). Direct coupling of this mechanism to the water of the sea is everywhere subsonic and reaches a maximum at the equator, but probably is insignificant even there.

A simple toroidal model has been constructed, which demonstrates the existence of streaming flow in a gas (CO_2) associated with a repetitive radiative pulse from an external source moving circumferentially through the gas at velocities of the order of Mach 1.

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Chemistry and Petrology of Venus: Preliminary Deductions

Abstract. *Recent measurements of the temperature of Venus suggest that a chemical interaction between the atmosphere and lithosphere may occur: the possible consequences of such interaction are examined. Results indicate that metallic iron, free carbon, and magnesium carbonates should not occur on the surface of Venus. Calcium carbonate, iron oxides and certain hydrous silicates may be present, but other hydrous silicates seem to be excluded. The effects of the physicochemical conditions on rock types and the various planetary processes are discussed.*

The relatively high temperatures (400° to 570°K) obtained during the flight of Mariner II (*1*) from microwave measurements of deep atmospheric layers indicate that the temperature of the surface rocks might be about 700°K (*2*). This temperature corresponds with those attained during moderately high degrees of metamorphism on Earth. It is therefore possible that large parts of the atmosphere of Venus are partially equilibrated with the surface rocks. From this assumption, it follows that the composition of the atmosphere should reflect the mineralogic character of the rocks.

The mass and density of Venus do not differ greatly from the corresponding values for Earth (*3*). It thus seems reasonable that planetary evolution has led to surface rocks on Venus which have representatives among the common types of terrestrial rock. For example, we should expect outpourings of both basic and acidic lavas and the corresponding shallow and deep-seated intrusives. However, there should also be significant differences which are related to the higher temperatures and the atmospheric chemistry of Venus. These differences should be most pronounced in the characteristics of the secondary rock types derived by sedimentation and metamorphism, although certain differences in igneous rocks should also occur.

One of the most important parameters is the oxidation state of the atmosphere as revealed by the ratio of the fugacities or partial pressures of carbon dioxide and carbon monoxide (pCO_2 to pCO). Spectroscopic data for Venus indicate that the lower limit for the ratio pCO_2 to pCO is about 10^3, with no detectable carbon monoxide (*3*). However, a small amount of CO may have been detected recently (*4*). Also, the spectra indicate that pCO_2 is approximately equal to 10 atmospheres (*2, 3*), although this should only be regarded as an order of magnitude value since the reflecting layer is probably not at the base of the atmosphere.

The stability fields of the iron oxides as determined from thermochemical data (*5*) show that the limiting value of pCO_2 to pCO corresponds approximately to the center of the magnetite field at 700°K. Higher values could extend to the field of hematite, however, and this extension would be possible without pO_2 exceeding 10^{-21} atm. This is significant in interpreting the failure to detect oxygen. Therefore, the data seem to indicate that metallic iron is not present in the surface rocks of Venus, but if these rocks do lie in the field of hematite, one would expect most of the iron to occur as oxides rather than silicates of iron. Since the latter consist chiefly of ferrous oxide, they would tend to be unstable under highly oxidizing conditions (*6*). Thus, if a quasi-equilibrium exists on Venus, the low values of pO_2 may correspond to a buffering of the atmosphere by the great mass of the lithosphere.

There are interesting questions concerning the stabilities of water and the reduced carbon species on Venus. The water-gas reaction shows that pCO_2 to $pCO \geq 10^3$ corresponds to pH_2O to $pH_2 \geq 10^{2.1}$ at 700°K. For the hydrocarbons, reaction 1 is informative

$$2H_2 + 2CO \rightleftharpoons CO_2 + CH_4 \qquad (1)$$

The relation between the equilibrium constant and the gaseous fugacities is

$$\frac{p^2CO}{pCO_2} K = \frac{pCH_4}{p^2H_2} \qquad (2)$$

At 700°K, $K = 10^{4.52}$, and if pCO to $pCO_2 = 10^{-3}$, then pCH_4 to $p^2H_2 = 10^{-0.48}$. Thus reaction 1 is displaced to the left by the oxidizing conditions. Polymers in the higher paraffin series would be even less abundant.

The stability of free carbon may also be evaluated by the use of the reaction

$$CO_2 + C\ (\text{graphite}) \rightleftharpoons 2CO \qquad (3)$$

where the equilibrium constant is $10^{-3.68}$ at 700°K. At the limiting value of 10^3 for the ratio pCO to pCO_2, this corresponds to $10^{2.32}$ for pCO_2, which is greatly in excess of the observed value. Thus the atmosphere is probably too oxidizing for free carbon to exist at the pressure attained at the rock surface.

The upper limit on pCO_2 of perhaps a few tens of atmospheres also permit deductions of the stability relations of certain carbonate phases. These deductions are subject to the uncertainties in the thermochemical data which may be considerable for the more complex minerals. Unfortunately, experimental data do not extend to the low fugacity range needed here. According to Week's data (*7*), the magnesium carbonates, magnesite and dolomite, should not be stable in the presence of free silica, but calcite might be stable with silica under the conditions of temperature and fugacity of carbon dioxide which is inferred for Venus. However, the stable occurrence of dolomite in the absence of free silica does seem possible.

The occurrence of the important class of rock-forming hydrous silicates is more doubtful. Extrapolation of data obtained by Robie (*8*) shows that at 700°K, the pH_2O for the reaction

$$\overset{\text{Tremolite}}{Ca_2Mg_5Si_8O_{22}(OH)_2} \rightarrow \overset{\text{Diopside}}{2CaMgSi_2O_6} + \overset{\text{Enstatite}}{3MgSiO_3} + \overset{\text{Quartz}}{SiO_2} + \overset{\text{Gas}}{H_2O} \quad (4)$$

is only 0.04 atm. From this it would seem that very small amounts of water in the rocks of Venus would be adequate to stabilize tremolite. In contrast, the pH_2O at 700°K in the reaction

$$\overset{\text{Talc}}{Mg_3Si_4O_{10}(OH)_2} \rightarrow \overset{\text{Enstatite}}{3MgSiO_3} + \overset{\text{Quartz}}{SiO_2} + \overset{\text{Gas}}{H_2O} \quad (5)$$

is 2200 atm. While confined to much higher temperatures, the experimental data of Yoder and Eugster (*9, 10*) seem to indicate that certain micas might also be stable in the rocks of Venus.

The atmosphere of Venus apparently shows signs of vigorous convection as indicated by the spectra and cloud colors (*3*); the latter may be caused by rock dust. Convection should not only aid in achieving the observed uniform circumplanetary temperatures (*1*), but should also make wind erosion one of the dominant modifying forces of the surface rocks. In addition, the finely divided state of the rock dust would aid in the chemical equilibration with atmospheric gases.

The interaction of the atmosphere and lithosphere of Venus suggested here appears to be in conflict with the recent interpretation of Sagan (*2*), who proposed that the high CO_2 pressure may be attributed to the failure of the carbonation equilibrium of $MgSiO_3$. The calculations of Weeks (*7*) referred to here indicate that the equilibrium values of pCO_2 over the magnesium carbonates, magnesite and dolomite, are higher than the deduced lower atmospheric values by hundreds of atmospheres at 700°K. Also, Sagan did not differentiate such compounds as $CaCO_3$, which have stability fields very different from $MgCO_3$ and $CaMgC_2O_6$. Thus, the high content of atmospheric CO_2 may be largely a result of the high temperature of the lithosphere.

Because of the similarity in scale of Venus and Earth it seems reasonable to suppose that similar orogenic processes occur on the two planets, sedimentary subsidence basins and metamorphic cycles also being features of the planetary history of Venus. The sediments should consist of wind-borne materials, and, assuming that water is scarce in the lithosphere, the dominant initial lithification process should be sintering. A relatively weak crust, and therefore a low relief, might be expected because of the higher temperature. If chemical equilibrium is approached on the surface, one might also expect the plutonic rocks to be undergoing a continuous transition during elevation and exhumation, so that relics of deep seated processes would be rare on the surface.

Some of the major unknown factors in the foregoing analysis are: (i) the rates of attainment of the equilibria; (ii) the competition between certain photochemical reactions in the upper atmosphere with the thermochemical equilibria; and (iii) the differential movement of various species from the planetary interior and their loss into space. In this regard it seems highly significant that no hydrogen compound has yet been detected on Venus. This agrees with the expected greater rate of loss of hydrogen as compared with the cooler or more massive planets. In general, the character of the atmosphere as discussed here is consistent with this hypothesis (*11*).

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Light-Induced Inhibition of Potato Tuber Sprouting

Abstract. *In freshly harvested Alaska-grown potato tubers there is a "rest period" during which time no sprout growth can be visibly detected. This is followed by a physiological stage of development when sprout growth will occur in the dark but is suppressed by light. Following this is a stage of gradual resumption of growth of light-suppressed sprouts and a lessening of the inhibitory responses in tubers planted at successive lengthening periods of time after harvest.*

Visible radiation causes many types of metabolic, tropic, and morphogenic responses in plants (*1*). Little research has been conducted on specific photomorphogenic responses of the potato plant or tuber. Wassink *et al.* (*2*) observed a strong, light-induced suppression of sprout growth in tubers that had been desprouted and were not planted. Their data do not, however, indicate the physiological stage of development of the potato tubers nor the length of time after harvest that the experiment was conducted. No reports have been found in the literature of potato tubers exhibiting a differential response at different physiological ages, in sprout or shoot growth as influenced by light. During studies of the nature of the "rest period" (*3*) of tubers a suppression of shoot elongation and leaf expansion by light has been observed in Alaska-grown potatoes. This photomorphogenic response is apparently restricted to a particular physiological stage of development in potato tubers.

Recent review articles by Burton (*4*) and Bruinsma (*5*) summarize the European, American, and Japanese literature on the physiology of "dormancy" in potato tubers. No reasonable explanation of the "dormancy" or "rest period" of tubers has been proposed as a result of much research effort into the nature of the phenomenon. The observations reported here may aid in an explanation of the potato tuber "rest period" and understanding of the postharvest physiology.

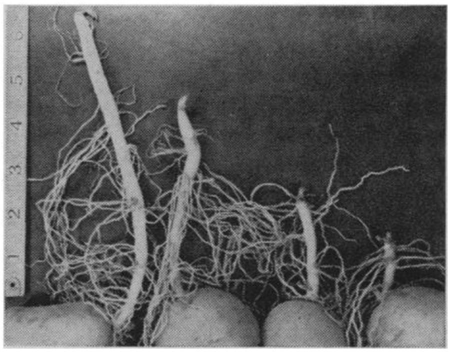

Fig. 1. Sprout growth on tubers that were planted the same date at 6, 4, 2, and 1 inches deep in sand. Typical root growth and light suppression of sprout tips at the sand surface are illustrated.