activity, pyroclastic activity requires exsolved magma volatile contents in excess of several weight percent. Thus unless these special conditions prevail, pyroclastic deposits and landforms should be very uncommon on Venus. Our treatment leads to a series of predictions concerning the detailed nature of deposits (Figure 16) and resulting landforms (Figures 17-18). Preliminary analyses of Venus radar images show evidence of extensive lava flows (some best explained by very high, lunarlike effusion rates), large low shield volcano structures, locally abundant cone/dome structures, and one possible example of a regional pyroclastic deposit. The treatment outlined here and summarized in Figures 16-18 has allowed possible modes of origin of these features to be specified and provides a framework for the interpretation of subsequent observations of the surface of Venus.

6.2. Past Volcanic Environments

It is widely accepted that the present-day pressure and temperature regime on Venus may not have been present throughout the history of the planet and that both parameters may have been smaller in the past. Most studies [e.g., Donahue et al., 1982] place the evolution of current conditions at an early, rather than late, stage of solar system history.

Using our general eruption modeling calculations [Wilson and Head, 1983], we can readily explore the consequences of assigning any pressure and temperature values to the Venus environment. However, it is less easy to know what associated pairs of values to assign as a reasonable representation of the evolving Venus atmosphere, since the prediction of the atmospheric temperature from the pressure and composition is a complex problem. Furthermore, at lower pressures the current slow rotation rate of Venus becomes ever more important as regards the disparity between dayside and nightside temperatures, and it becomes progressively more important to know if the planetary rotation rate should be changed to higher values in the past. Fortunately, calculations show that the decrease in pressure will be much more important than the decrease in temperature for most volcanic processes. However, the temperature decrease will have a significant effect on increasing the mobility of pyroclastic flows: if the greenhouse effect were absent from the Venus atmosphere, temperatures at the surface would still be greater than those on Earth because of the greater solar flux. As a result, the run-out distances of pyroclastic flows would then approach (but still not quite equal) those of terrestrial equivalents when the atmospheric pressures were equal.

The main effect of changing conditions on lava flows would be that a reduction of atmospheric density with decreasing pressure would lead to less efficient cooling of the flow surfaces. As we have shown in detail earlier, a pressure reduction to Earth-like conditions would lead to only a 10-30% change in any of the morphological parameters. Even if the pressure were to fall to zero, so that only radiative cooling operated, cooling rates would vary by less than the change from present-day Venus to present-day Earth conditions, leading to a negligible further modification in flow morphologies due to cooling alone. It is possible, however, that large pressure reductions might lead to systematic changes in flow morphology induced by corresponding changes in rheology of the erupted magmas as volatiles were lost by exsolution.

The other major consequence of assuming lower atmospheric pressures on Venus is the increased likelihood of explosive activity in any type of magma (as long as there are at least some volatiles present). Steady explosive activity (Hawaiian or Plinian) will occur at ever lower magmatic gas contents as the pressure is reduced, will result in more thorough disruption of the magma (hence producing finer-grained pyroclasts), and will lead to increasing eruption velocities, increasing eruption cloud heights, increasing dispersal of air fall and pyroclastic flow deposits, and decreasing values of the size of the largest pyroclast which can be transported to a given range in the deposit.

An impression of the absolute changes in all these parameters can be obtained by examining values given for the environments of Venus, Earth, Mars, and the moon by Wilson and Head [1983]. These calculations show that the dispersal parameter changes are not linear with the pressure changes: a two-order-of-magnitude pressure decrease to terrestrial values leads to no more than a 50% increase in dispersal of most kinds of pyroclastics, whereas a four-order-of-magnitude decrease of pressure to Martian values would yield about a sevenfold increase in dispersal distances.

Since lava flow morphologies are so insensitive to environmental conditions, we cannot expect to infer useful information about the history of the planetary atmosphere by examining lava flow deposits. Of much greater value is likely to be recognition of the presence or absence, at successive levels in the stratigraphic sequence, of numerous, large-scale air fall or pyroclastic flow deposits. There could, of course, be an ambiguity in interpreting the significance of the presence of such deposits, since without separate information on the volatile contents of the magmas erupted we would have no way of deducing the atmospheric pressure reduction required to allow an eruption of the appropriate kind to take place. It is possible that magma volatile contents could be at least approximately estimated for some kinds of pyroclastic deposits: Wilson [1976] and Wilson et al. [1980] have shown that the sizes of the largest clasts found in a Plinian air fall or pyroclastic flow deposit in the vicinity of the vent can be used to determine the magma volatile content if the ambient pressure is known. In the Venus case a series of atmospheric pressures would be assumed, and for each, the clast size information would be used to obtain a volatile content; the combination of volatile content and pressure would then allow an assessment to be made of the likelihood of formation of the deposit observed. Unfortunately, this may not be a practicable way of interpreting pyroclastic deposits on Venus since pyroclast sizes in the meter size range cannot easily be deduced using radar systems: clast size is likely to be confused with general meter-scale roughness.

We can, however, make some deductions about past atmospheric conditions on Venus. The survey of about 30% of the Venus surface carried out by