surface rocks is likely to be by chemical and thermal processes rather than by wind-blown particles.

Our knowledge of the surface composition is based partly upon measurements of radioactivity made by Veneras 8, 9 and 10. The first of these indicated a similarity to terrestrial granites, and the others a close resemblance to both terrestrial and lunar basalts. The more sophisticated techniques used on Veneras 13 and 14 (using drilling and X-ray fluorescence) found an unusual high-potassium basalt, with some similarities to lunar highlands and terrestrial continental rocks, and a type similar to that of the Earth's ocean floors. Veneras 9, 10, 13 and 14 returned pictures of the areas surrounding their landing places (the last two in colour). The first, in particular, proved to be surprisingly rough; the others were generally smoother, suggesting that erosional processes are at work. Veneras 10 and 13 showed flat rock outcrops with intervening patches of darker 'soil' fragments. The view from Venera 14 was somewhat different, with just a flat, apparently layered rock expanse, but the layers in themselves are rather difficult to understand and have been proposed as either cemented fine particles or thin layers of the original lava.

Atmosphere

The dominant constituent of the atmosphere is carbon dioxide (CO_2) and this amounts to 97 per cent of the total mass. The overall quantity of carbon dioxide is approximately the same as the total held by the combined oceanic, rock and atmospheric reservoirs on Earth, implying that both planets were formed with, or have accreted, similar quantities of the gas. A considerable number of other components of the atmosphere have now been identified. Particularly significant is the very small amount of water (H_2O) and this will be discussed below.

Because of the vast amount of carbon dioxide, the atmospheric mass and surface pressure are both about ninety times that of the Earth (Fig 5·12). As a result of the carbon dioxide's greenhouse effect (page 95), the surface temperature has been raised to the very high level of 760 K, comparable to, if not hotter than, that at the surface of Mercury. However, there is now considerable evidence that these high temperatures have not prevailed throughout the planet's history.

The extreme surface temperature is, of course, far above the boiling point of water, and it was a matter of some surprise when early radio studies showed that the atmosphere contains very little water vapour. Subsequent direct measurements agree with this, and although there are some discrepancies, lie in the range of 0·1 to 0·01 per cent. This scarcity is very difficult to understand unless Venus was formed from very different material than the Earth, or accreted its atmosphere in a different way. But there is direct evidence that Venus once had a very considerable quantity of water. This information comes from a determination of the ratio of hydrogen to deuterium (heavy hydrogen). There is far more deuterium on Venus than on Earth, and this shows that a large amount of water was once present, indeed that oceans probably existed. The greenhouse effect would cause this liquid water to be evaporated into the atmosphere (incidentally contributing to a still stronger trapping of infrared radiation), and the water molecules would be dissociated by the Sun's ultraviolet radiation at the top of the atmosphere. The ordinary light hydrogen atoms would be most easily lost to space, but the heavier deuterium isotope would be retained, leading to its present high concentration. The free oxygen is likely to have been incorporated into surface rocks, and it has been suggested that the oxidation process would further increase the heating of the crustal layers. However, it does seem likely that Venus had large bodies of water at an early period in its history, and it is by no means impossible that some form of life did originate upon the planet before the runaway greenhouse effect made it too hot for any life forms.

The structure and composition of the clouds long remained a mystery, but has now been reasonably well established. The yellowish tinge is probably due to the presence of sulphur (S), while the dark markings, which show up strikingly only in ultraviolet wavelengths, are most probably caused by

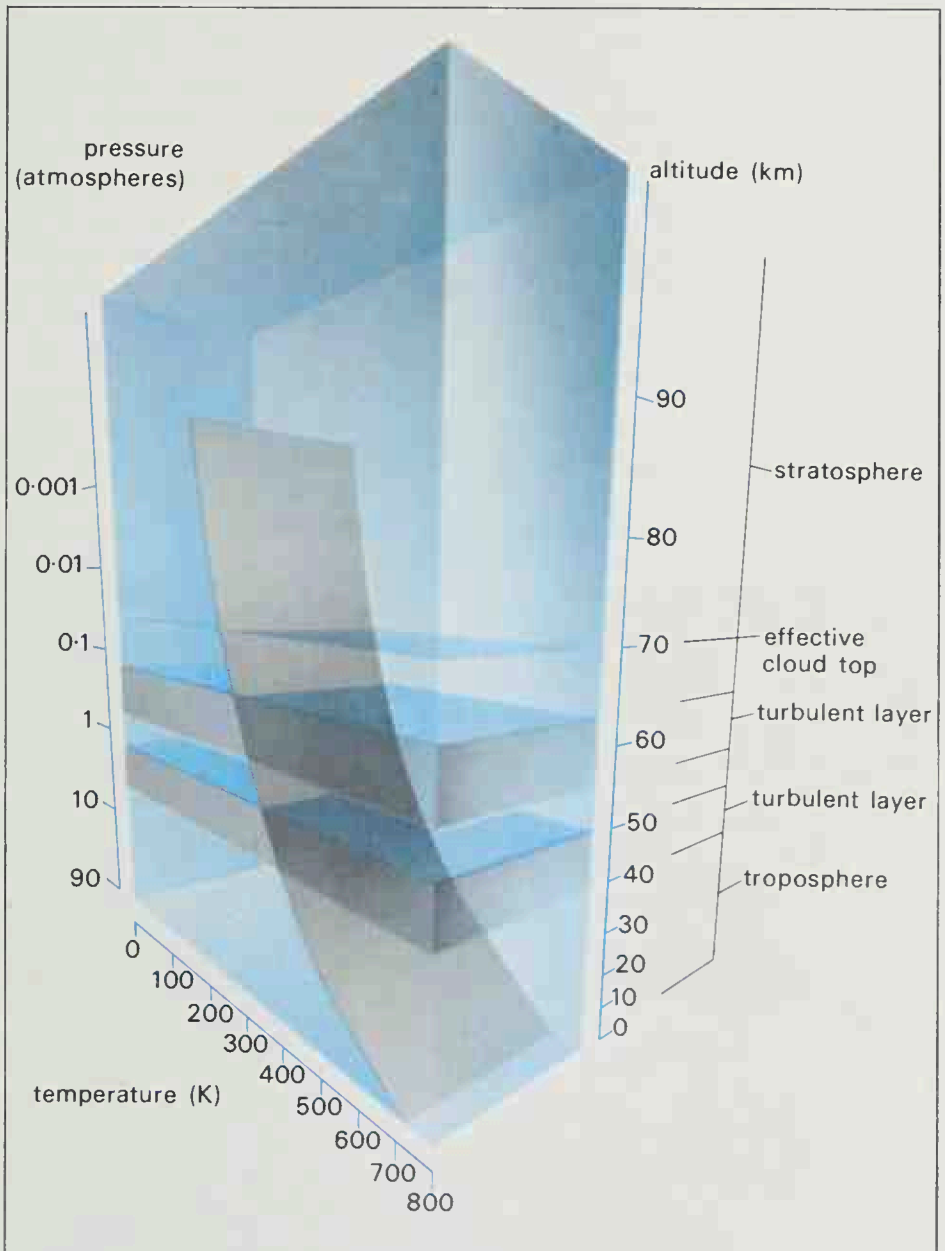

Fig. 5·12
The structure of the atmosphere of Venus. Atmospheric particles (cloud droplets) reach a peak between 40–50 km and are largely absent between 10–30 km.