tionary track ends at γ, in the reducing portion of the diagram. The actual present atmosphere of Venus appears to have a [C/O] ratio that differs from that of CO_2 by an amount of 10^{-5} or less.

If the initial atmosphere had a C/O ratio anywhere between 0.2 and 0.7, the probability that the present ratio would be as close to CO_2 as it appears to be, through no other process but the loss of hydrogen, would then be about 4×10^{-5}. This seems quite unlikely. However, if oxygen were also depleted from the atmosphere, then over a wide range of initial [C/O] ratios the atmosphere would finally settle at the CO_2 point. Since it seems unlikely that oxygen has escaped from Venus, the depletion of atmospheric oxygen must be attributed to chemical reactions, and the surface material of Venus, initially reducing, must now be partially oxidized to a considerable depth. Accordingly, there must have been some active weathering agent, such as extensive wind erosion, to disturb and expose a sufficient volume of surface material to allow for efficient reactions with oxygen. An independent argument for the presence of extensive oxygen sinks on the surface of Venus has been offered by Sagan (*19*), in an attempt to explain the differential abundance of water on Venus and on Earth by differential rates of water photodissociation.

Typical evolutionary tracks would then have resembled those illustrated by the arrows in Fig. 2. Owing to loss of hydrogen, the atmosphere evolves away from the hydrogen corner of the ternary diagram until it intersects the oxidation threshold. As soon as free oxygen is produced, it combines with surface material and the evolutionary track turns abruptly upward, following the oxidation threshold toward the CO_2 point.

If the initial [C/O] ratio were near 0.44, the initial evolutionary track due to the loss of hydrogen would twice intersect the graphite threshold (see Fig. 2). There would then be an interlude in the evolutionary history of Venus in which graphite might be present. However, the activation energy for the formation of graphite is so great that it would very likely never precipitate directly. If it did, it would react and disappear at the high temperature of Venus as the system lost more hydrogen. Such a track would follow the line marked H-β in Fig. 2 until it intersected the oxidation threshold, whereupon it would turn and proceed toward the CO_2 point.

If the initial [C/O] ratio had been perceptibly above 0.5, as, for example, 0.67, the evolutionary track would follow the line marked H-γ in Fig. 2. This line intersects the graphite threshold once, and never crosses the oxidation threshold. The atmosphere would then always remain in the reducing portion of the diagram. In order to end at the CO_2 point, some mechanism would have to exist for the removal of carbon from the atmosphere or the addition of oxygen to it. The asphalt threshold is not intersected, so no formation of polycyclic aromatics would be expected. If the removal of carbon from the atmosphere were possible by the precipitation of graphite, the atmosphere would then evolve along the graphite line. As the C—O line was approached, any such exposed, precipitated graphite would undergo equilibrium reactions with the atmosphere and disappear. The composition would end significantly above the actual composition point, where the CO concentration would be 10^{-3}. This is in conflict with the spectroscopic observations. While the outgassing of water, photodissociation, and hydrogen escape could conceivably increase the O_2 abundance over a surface which was *not* highly reducing, the addition of precisely enough O_2 to bring the atmosphere to its present unique composition very close to the CO_2 point is highly implausible. It is interesting to note that if the temperature of Venus were much lower, for example, 500°K, graphite could exist in equilibrium with the observed atmosphere, if a mechanism were available for its formation. However, no complex organic compounds would be stable even under these conditions.

Thus, it is probable that Venus began its evolutionary history with [C/O] $\leq$ 0.5 and that its evolutionary track in the ternary diagram was directed towards the CO_2 point by the simultaneous loss of hydrogen to space and oxygen to the surface.

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Weight Loss in Men in Space

Abstract. *Men returning from orbital flights have lost from 2 to 6 percent of their body weights. Similar losses occur during simulated weightlessness; blood normally pooled in dependent parts returns to the circulation, increasing central blood volume and causing excretion of water which is not replaced during flight.*

Astronauts lose weight during orbital flights. All medical data reported from the United States and Soviet manned flights tell of loss ranging from 2 to 6 percent of initial body weight (Table 1). Such loss is independent of the duration of flight; that is, losses in this range occur during flights as short as three orbits as well as during missions lasting from 1 to 14 days.

Although manned flight in space has produced very few medical surprises, this consistent loss of weight is a definite change, a readjustment of some sort. Most of the loss is quickly regained after the flight, usually within 24 hours, suggesting that the loss is primarily of water.

Does the loss reflect simple dehydration? Most of the evidence suggests that it does not. Several features of space flight increase the amount of water lost from the body. There is more insensible loss of water by increased cutaneous diffusion in the low pressure (about 0.33 atm) in U.S. spacecraft, although the magnitude of loss is independent of flight duration. Cabin pressures in Soviet spacecraft have approached 1 atm. Perspiration is increased by the wearing of impermeable, full-pressure suits, and nonthermal sweating may be great, even though the environmental cooling has been generally adequate and the astronauts have seldom complained of heat. The most important argument against simple dehydration is that water was always freely available. I can think of nothing in space flight that would alter thirst or the ability to replace lost water by drinking.

A readjustment of the water content of the body seems more likely. In studies of prolonged bed rest and of immersion in fluid, states which partially simulate the physiological effects of weightlessness, production of urine is often increased and body weight is regularly lost during experiments lasting more than 1 or 2 days (*1*). For example, in my laboratory a man has been submerged in silicone fluid for 120 hours (*2*)—roughly five times longer than the longest experimental immersion in water. (Unlike water, the silicone fluid causes no maceration of the skin or other problems of skin hygiene.) Loss of body weight was 3 percent, with no particular change in the pattern of fluid intake and output and with return to the former weight within 36 hours. Simple confinement in a space-cabin simulator for 2 to 4 weeks (*3*) or resting in a chair for 4 to 10 days (*4*) produced similar weight losses. Most of these studies report concomitant loss in plasma volume and increase in hematocrit.

Table 1. Weight loss during space flight (*8*).

Astronaut	Flight		Loss of body weight	
	Vehicle	Duration (days)	Abs. (kg)	Percentage
Gagarin	Vostok 1	0.1	0.5	0.7
Titov	Vostok 2	1	1.8	2.9
Nikolayev	Vostok 3	4	1.8	2.6
Popovich	Vostok 4	3	2.1	2.8
Bykovskiy	Vostok 5	5	2.4	3.6
Tereshkova	Vostok 6	3	1.9	3.3
Komarov	Voskhod I	1	1.9	2.7
Feoktistov			2.9	4.0
Yegerov			3.0	3.9
Belyayev	Voskhod II	1	1.0	2.0
Leonov			0.9	2.0
Glenn	Mercury-Atlas 6	0.2	2.4	3.1
Carpenter	Mercury-Atlas 7	.2	2.7	3.9
Schirra	Mercury-Atlas 8	.4	2.0	2.8
Cooper	Mercury-Atlas 9	1.4	3.5	5.2
Grissom	Gemini-Titan 3	0.2	1.2	1.7
Young			1.6	2.1
McDivitt	Gemini-Titan 4	4.0	2.0	2.9
White			3.9	4.9
Cooper	Gemini-Titan 5	8.0	3.3	4.9
Conrad			3.9	5.5
Schirra	Gemini-Titan 6	1.1	1.1	1.3
Stafford			3.8	4.9
Borman	Gemini-Titan 7	13.8	4.5	6.2
Lovell			2.9	3.7

An explanation of the loss of water during real and simulated weightlessness may be found in the regulation of central blood volume by the action of volume receptors (*5*) that are thought to exist in the great veins of the thorax and the cardiac atria. In reviewing experiments with immersion in water, Gauer *et al.* (*6*) considered the effects of release of the 400-to-600 ml of blood that is normally pooled in the dependent extremities at 1*g*. The extra blood in the venous return produces a volume change in the central veins, causing increase in production of urine, by suppression of the antidiuretic hormone. McCally (*7*) reviewed the mechanisms for regulation of the volume of body fluid, and the renal response of human subjects to immersion in water; he proposed a similar antidiuretic-hormone mechanism for readjustment of water content during simulated weightlessness.

If the initial loss of water from the circulating plasma (whether by diuresis or by increased loss of water in other ways) is not compensated by drinking, rearrangement of water content in the other fluid compartments of the body may be expected, at least after several days. There is preliminary evidence (*8*) of such readjustment during the longest Gemini flight when, however, there was change in other conditions: for example, space suits were worn during only part of the flight. During the 14-day flight of Gemini 7 the astronauts suffered considerable loss of weight without change in circulating blood volume and with only slight increase in plasma volume. This fact can be interpreted as loss of water from the extracellular, and possibly intracellular, fluid compartments.

In medical practice, clinical dehydration amounting to 2 to 5 percent of body weight would normally be treated by replacement of fluid. During space flight, replacement of fluid is inappropriate if the weight loss reflects natural readjustment of water content following the return of blood normally pooled in the extremities. On return to Earth and the 1*g* environment, blood is again pooled in the extremities, and symptoms of orthostatic intolerance appear (*8*). It is not clear whether the reduced water content during weightlessness has harmful effects.

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Rates of Surficial Rock Creep on Hillslopes in Western Colorado

Abstract. *The average rate of downslope movement of rock fragments on shale hillslopes is directly proportional to the sine of the slope angle or that component of the gravitational force which acts parallel to the hillslope. The rates of surficial rock creep range from a few millimeters per year on a 3-degree slope to almost 70 millimeters per year on a 40-degree slope, but these rates vary with natural variations in soil characteristics and microclimate, as well as with accidental disturbances.*

Information on rates of landform erosion and evolution has been increasing steadily during recent years; however, it is rare that the data are adequate to establish a statistical relation between the rate at which erosion progresses on hillslopes and the factors determining these rates (*1*). A 7-year record of the downslope creep of rock fragments on eight hillslopes has been obtained as part of a study of the erosion and hydrology of landforms developed on the Mancos shale of Late Cretaceous age in western Colorado (*2, 3*), and these data illustrate the relation that exists between rates of rock creep and hillslope inclination, as well as the great variability that occurs among data collected in this manner.

Thin platy fragments of sandstone weather out of the Mancos shale and occur scattered over the shale hillslopes. One hundred and ten of these rock fragments, which ranged in thickness from 3 to 6 mm, and from 25 to 75 mm in maximum dimension, were marked with a small dot of aluminum paint. These rocks were then placed along transects normal to the hillslope contours, and the position of each rock was established with reference to metal stakes driven into the slopes. Hillslope angles were measured over a 30.5-cm (1-foot) length of slope extending downslope from each marker. The downslope movement of each rock was obtained by repeated measurements of its progressively increasing distance from a reference stake, which remained fixed in bedrock. The positions of the stakes did not change during the study, and therefore the bedrock was stable. The marked rocks were placed on the transects in 1958 and measurements of rock movement were made yearly in the spring and autumn between September 1958 and September 1962. A final measurement was made in September 1965.

The hillslopes on which the rocks were placed are located in two small drainage basins about 8 km northeast of Montrose in western Colorado. These basins drain to the west from a divide which forms the western edge of Bostwick Park (U.S. Geological Survey, Red Rock Canyon, 7½ minutes topographic map).

The Montrose study area has been described in some detail in previous publications (*3*). Annual precipitation at the Montrose (No. 2) weather station is 23.1 cm (9.1 inches). During the 7-year period of investigation 172.7 cm (68 inches) of precipitation fell at this station (*4*). Maximum relief within the drainage basins is about 76 m. The slopes are sparsely vegetated with shadscale, saltbush, and forbs. All hillslopes have a convex summit, and where they are not graded directly to a channel, they have a lower concave segment which is separated from the summit convexity by a straight segment.

The Mancos shale, which underlies all of the hillslopes, is a saline marine shale. Frost action in the weathered shale mantle is the major factor causing downslope creep of the weathered shale lithosol and the rocks. During the winter the surface of the slopes is loosened and heaved by the formation of granular ice crystals in the upper few inches of the lithosol. The loosened surface is subsequently compacted by summer rainbeat. This annual cycle of heaving and compaction is an effective mechanism causing episodic creep of the soil surface (*3*). Some disturbance of the slopes also occurs when sheep move through the area enroute to seasonal pastures.

Of the original 110 rocks placed on the slopes in 1958, 30 could not be located in 1965. Some of these were lost by burial, others were displaced from the profile by the trampling of livestock, humans, or other animals, and some undoubtedly were lost because their identifying paint mark was obliterated. Of the remaining 80 rocks, eight were eliminated from this analysis either because they showed an unusually large amount of movement during one measurement period, which suggested a disturbance other than that caused by the natural processes that generate creep, or because they showed a negative or upslope movement, which was considered adequate proof of disturbance.

The average rates of rock creep (velocity in millimeters per year), as measured for the 7-year period from September 1958 to September 1965, for each of the remaining 72 rocks are plotted against the sine of the angle of slope inclination in Fig. 1.

The rate of rock creep is directly proportional to the sine of hillslope inclination (s): velocity $= 102\ s - 0.7$, or essentially velocity $= 100\ s$. The coefficient of correlation is .77, indicating that 59 percent of the total variation is explained by slope inclination alone. The coefficient of correlation is significant at well above the .001 level. The sine of the hillslope angle is used because it is proportional to that part of the total gravitational force which acts along the surface of the slope (*5*).

Earlier I had concluded that the relation between slope angle and marker movement was exponential (*3*). That relation was derived from an analysis of the data obtained during the period 1958 to 1961. I now consider it incorrect, because I calculated the relation by averaging the rates of movement of various types of markers (painted rock fragments, metal washers, and wooden blocks) which behaved differently. Raindrop impact accelerated the rate of movement of the wooden blocks, whereas many of the washers were buried and therefore moved more slowly than the rocks. No attempt was made at that time to consider each measurement separately, as the objective then was to demonstrate the episodic or seasonal rates of movement (*3*).