

Fig. 1. Stratified sand containing gas in interstitial waters, illustrating the effects of gas on the mode of failure of the sediment. After gas leaves the solution in tilted beds (5° from horizontal), the mass fails by flowage as folds develop. (Note spiral roll at left.) Conversely, sand, either wet or dry, not containing gas, fails along shear planes and does not flow or fold.

still intact. The sand mass may also transport fragile pelecypods, which, in many cases, are preserved whole, sometimes with both valves still together. The grains of sand were entirely separated at the time of injection. The sandstone dikes, sand crumplings, spiral sand rolls, isolated spiral rolls, and other anomalous features commonly called slumping structures are usually found together. The cause of the fluidity of the sandstone dike materials may be the same as that of the fluidity required for the development of the flowage structures within the associated horizontal beds.

Most structures illustrating the fluidity of clastic materials are found in specific but seemingly diverse environments, including areas of petroleum accumulation and mud volcanoes, recent organic marine sediments, and strata contiguous to coal beds, glacial lake beds, and organic lake beds. These diverse environments have one characteristic in common: All of them are associated with large quantities of organic materials deposited under euxinic conditions.

As Sugden (2) has stated, "the vast majority of submarine slumps occur in sediments which have been recently deposited and particularly in sediments which must be supposed to have been rapidly deposited." The burial of large quantities of organic material under these euxinic conditions results in the formation of methane which saturates interstitial waters. The unconsolidated sediment is thereby capable of immediate elastic expansion, which results in pressure equalization throughout the volume of sediment. If a crack opens, the unconsolidated sediment expands

immediately to fill it. The strength of the sediment is diminished to that of a fluid, since the grains of that sediment are separated by gas bubbles. In this way, clean sands can invade cracks within overlying shales at the instant the crack opens, without abrading the delicate shale projections observed later in the containing walls. When a horizontal layer of uncemented sand is saturated with gas, this fluid supports the total superincumbent load. Grains of sand are resting upon each other but are not bearing the unidirectional pressure of the overlying sediments. Any shift in weight of overburden results in an immediate rearrangement of the sand grains within the horizontal bed. The horizontal sand mass is capable of immediate expansion into continuously shifting low-pressure areas as the overlying sediments slump or slide, causing the typical slumping structures so often observed.

I demonstrated the flowage of stratified sand by means of a pressure tank, containing stratified sand and interstitial water saturated with CO_2 . Reduction of pressure in the tank caused gas to leave solution, resulting in slumping structures (Fig. 1).

This same mechanism, that of dilatancy resulting from interstitial waters saturated with gas, affects the stability of marine sediments, forming structures which help to identify source beds of petroleum.

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Equilibration of Atmospheric Carbon Dioxide with Sea Water: Possible Enzymatic Control of the Rate

Abstract. *Surface and subsurface ocean water differ in exchange characteristics with atmospheric carbon dioxide. The possibility of control by an enzyme like carbonic anhydrase has been experimentally explored.*

It has been discovered (1) that sea waters can differ markedly in their rates of equilibration with atmospheric CO_2 . In surface waters the C^{14} content resulting from nuclear weapons tests is on the average less than half that in

tropospheric air, and it is only in a matter of years (2, 3) until full equilibrium is reached.

It has been well known for some time now (4) that in the analogous problem in mammals—namely, the

Table 1. Carbon dioxide exchange rates for sea water. Samples (200 liters) in polyethylene-lined barrels were capped, trucked to China Lake, and aerated at approximately 200 liter/hr for the indicated period, with or without addition of the enzyme carbonic anhydrase (CA). (No temperature corrections are applied).

| Sample No. | Date | Initial ΔC^{14} * | Treatment | | Final ΔC^{14} * | Exchange time (days)† |
|--|-----------------------------|---------------------------------|-----------|-------------|-------------------------------|-----------------------|
| | | | CA (mg) | Time (days) | | |
| <i>Surface waters (Santa Monica Beach at foot of Sunset Boulevard)</i> | | | | | | |
| 1 | 12/22/65 | 14.9 | None | 17 | 17.3 | 460 |
| 2 | 1/8/66 | 15.1 | None | 68 | 22.7 | 480 |
| 3 | 4/12/66 | 15.4 | 100 | 14 | 47 | 19 |
| 4 | 5/12/66 | 14.0 | 100 | 3 | 29.6 | 10 |
| <i>200-foot well at Pt. Mugu Naval Station</i> | | | | | | |
| 5 | 3/9/67 | -4.7 | | 7.6 | 23.9 | 14 |
| <i>200-foot submarine (U.S.S. Baya) sample (off Catalina Is.)</i> | | | | | | |
| 6 | 5/26/67 33°20'N 118°17'W | 6.7 | | 3.0 | 34.2 | 5 |
| <i>200-foot submarine (U.S.S. Baya) sample (off Catalina Is.)</i> | | | | | | |
| 7 | 7/25/68 31°40'N 120°20'W | 20.7 | | 2.7 | 37.1 | 5 |

* ΔC^{14} is the deviation from the National Bureau of Standards oxalic acid standard expressed in percent. † See Table 2.

ready elimination of CO₂ from the blood for expiration in the lungs—that a special enzyme, carbonic anhydrase, is essential. So the question arises: Is there, perhaps, enzymatic control over the interchange of carbon dioxide between the atmosphere and the oceans?

Our procedure has been to take sea water samples (about 200 liters) in barrels lined with polyethylene to China

Lake—to avoid the Los Angeles smog—and aerate them vigorously with clean desert air (approximately 200 liters per hour for periods of days) to simulate wave action in the ocean. The aerated samples were then tested for C¹⁴ content. Figure 1 shows the course of the C¹⁴ content of the surface Mojave Desert air at this location over the last 7 years (analogous data from else-

where in the world are included for comparison).

Qualitatively our results show that (i) the exchange rate of surface waters (Santa Monica Beach) is very slow (1/470 day⁻¹ is the unimolecular rate constant); (ii) carbonic anhydrase at 100 mg/200 liters increases the rate very substantially (by about a factor of 20), as do 10 mg quantities; (iii) the exchange rate of water from a depth of 200 feet (60 m) is rapid and shows about the same characteristics as surface water to which the carbonic anhydrase has been added.

The general concentration of C¹⁴ in surface sea waters, as reported by Münnich and Roether (3) in 1967, are given in Fig. 2. Comparison of Figs. 1 and 2 shows that after several years the concentration in the sea still lags substantially behind that in tropospheric air.

In order to test the theory of a biochemically controlled rate, analogous to that found in mammalian systems, we have studied the waters off the Southern California coast both at the surface (samples 1-4) and at a depth of 200 feet (samples 5-7) (Table 1).

It is clear that Santa Monica beach waters lack some quality which waters off Pt. Mugu and Catalina Island at a depth of 200 feet possess. This quality is matched by the addition of 100 mg of carbonic anhydrase to 200 liters of the water.

Table 2. Exchange rate calculations.

$$C^{14}O_{2a} + CO_{2s} = CO_{2a} + C^{14}O_{2s}$$

$$\frac{[C^{14}O_{2a}]}{[CO_{2a}]} = \gamma_a$$

$$\frac{[C^{14}O_{2s}]}{[CO_{2s}]} = \gamma_t \quad \text{Eq. 1}$$

$$[C^{14}O_{2s}] = \gamma_o + (\gamma_a - \gamma_o)(1 - e^{-t/\tau})$$

$$[CO_{2s}] = \gamma_o e^{-t/\tau} + \gamma_a(1 - e^{-t/\tau})$$

γ_t and γ_o are measured, $(\gamma_a - \gamma_o)$ is calculated from Fig. 1, and τ from Eq. 1.

$$1 - \frac{\gamma_t - \gamma_o}{\gamma_a - \gamma_o} = e^{-t/\tau}$$

$$\tau = \frac{t}{-\ln\left(1 - \frac{\gamma_t - \gamma_o}{\gamma_a - \gamma_o}\right)}$$

| Sample | γ_o | γ_a | γ_t | t (days) | $(\gamma_t - \gamma_o)$ | $(\gamma_a - \gamma_o)$ | ln | τ (days) |
|--------|------------|------------|------------|---------------|-------------------------|-------------------------|-------|------------------|
| 1 | 14.9 | 80 | 17.3 | 17 | 2.4 | 65.1 | -.037 | 460 |
| 2 | 15.1 | 75 | 22.7 | 68 | 7.6 | 60.0 | -.14 | 480 |
| 3 | 15.4 | 75 | 47.0 | 14 | 31.6 | 60.0 | -.75 | 19 |
| 4 | 14.0 | 75 | 29.6 | 3 | 15.6 | 61.0 | -.31 | 10 |
| 5 | -4.7 | 65 | 23.9 | 7.6 | 28.6 | 70.0 | -.53 | 14 |
| 6 | 6.7 | 65 | 34.2 | 3.0 | 27.5 | 58.0 | -.63 | 5 |
| 7 | 20.7 | 63 | 37.1 | 2.7 | 17.1 | 42.0 | -.53 | 5 |

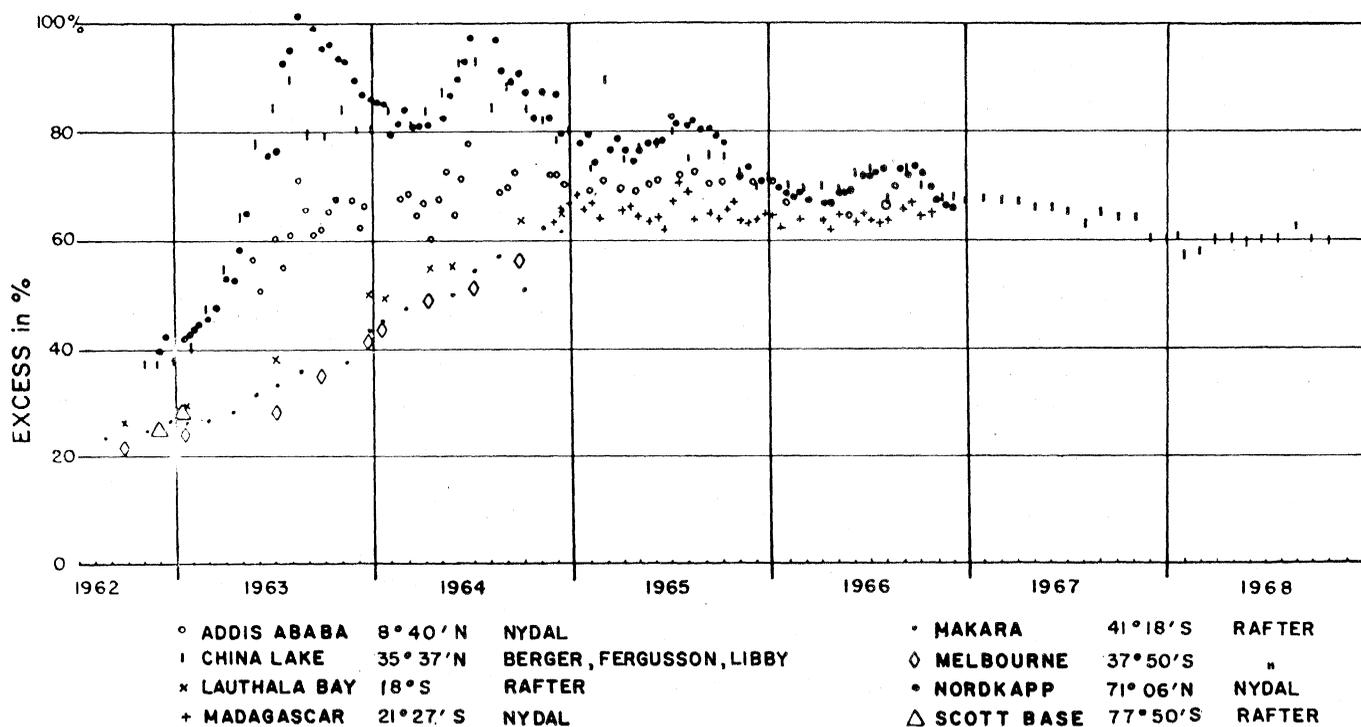


Fig. 1. Radiocarbon in atmospheric carbon dioxide.

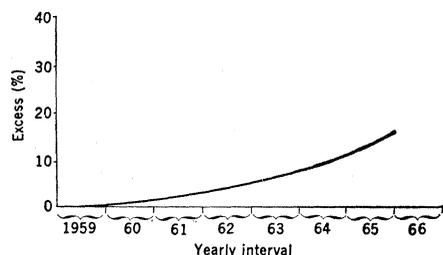


Fig. 2. Radiocarbon in ocean at 50°N.

In that only limited localities have been studied no very general conclusions can be drawn. However, the results suggest that (i) the quality may be due to an enzyme, like carbonic anhydrase, which might well be isolatable and may be derived from sea life known to produce it (5); (ii) there may be extensive areas of the sea that are devoid of the quality imparted by carbonic anhydrase and therefore slow to dissolve CO₂; (iii) that this quality may not long survive contact with air.

The rates measured here for Santa Monica beach surface waters agree well enough with the work of others (3), for the seas as a whole; therefore, we can have some confidence in the tentative conclusions. However, additional work is necessary to isolate and identify the enzyme and to measure its oxidative stability and to assay the waters of the seas for it.

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Peanuts: Gibberellin Antagonists and Genetically Controlled Differences in Growth Habit

Abstract. *Treatment of peanuts with gibberellin changed the orientation of lateral branches of runners to that of erect ones, and two growth retardants changed those of the erect type to a more horizontal orientation. Little or no difference was found in amounts of endogenous gibberellin in the two types of plants, but amount of native gibberellic acid antagonists was higher in runner plants. Furthermore, runner plants contained a particular gibberellic acid inhibitor not found in erect plants. Applications of various auxins, antiauxins, and a cytokinin had no effect on tropistic growth of the side branches.*

Commercial varieties of peanuts differ in their diatropic growth habit. Some are erect (bunch) whereas others are runner (trailing). Both types have an erect main stem, usually short in the runner type, which gives rise to lateral branches. In erect plants, the side branches are also erect or ascending in a 50° to 60° angle to the soil surface. In runner plants the cotyledonary and secondary lateral branches grow horizontally at an angle of 0° to 25°.

Growth habit is controlled by at least two kinds of cytoplasm, or plasmons, designated "V4" and "Others," and nuclear genes at two loci, *Hb₁* and *Hb₂* (1). In the "Others" plasmon *Hb₁Hb₂Hb₁Hb₂Hb₂Hb₁Hb₂Hb₁Hb₂Hb₂*, and *Hb₁hb₁Hb₂Hb₂* are runners, and all other genotypes yield bunch plants. In the "V4" plasmon the above genotypes and also *Hb₁hb₁Hb₂hb₂* give runner plants; all other genotypes produce bunch ones. Runner plants and erect plants of both plasmon types were used in this study (2).

Geotropic growth is usually considered to be controlled by amount and distribution of auxins (3). External applications of auxins, antiauxins, and phthalamic acid derivatives have been effective in modifying the geotropic response of various plants (3). Gibberellic acid (GA) also induces erect growth in diageotropic or plagiotropic branches of various species (4). Conversely, growth retardants which interfere with gibberellin biosynthesis (5) decrease the negative geotropic growth of shoots (6). In none of these reports was endogenous gibberellin concentration determined, although in several it was sug-

gested that gibberellin may be involved in geotropic movement of shoots.

In our study of the physiology of differences in the growth habit of peanut plants, we used true-breeding bunch and runner F₄ and F₅ lines derived from reciprocal crosses of V4 with N.C.2, and V4 with VSM. Initial attempts to modify the geotropic position of the shoots by external application of auxins, antiauxins, and cytokinins (7) failed in both erect and runner plants.

Treatments with gibberellic acid (1 to 100 ppm) and growth retardants, 2-chloroethyltrimethylammonium chloride (CCC, 20 to 2000 ppm) and *N*-dimethylaminosuccinamic acid [Alar (B 9), 100 to 10,000 ppm], modified the position of side branches of the plants (Table 1) (8). Treatment with GA changed the diageotropic growth of the runner type to an erect position; the growth retardants changed the negative geotropic growth of the erect type to a plagiotropic position. In other experiments the branch angle of the GA-treated runner type was even greater than that of the erect untreated controls, and erect plants treated with Alar were as prostrate as runner plants.

Thus, we assumed that the difference in growth habit of peanut plants re-

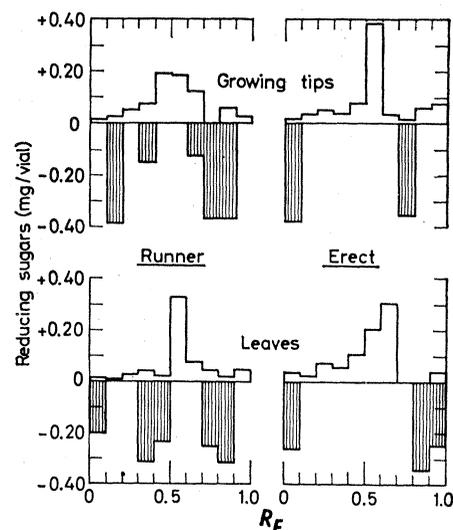


Fig. 1. Histograms showing promotion or inhibition of α -amylase activity by eluates from chromatogram strips developed with a mixture of isopropanol, ammonia, and water (10:1:1) when tested by the barley endosperm bioassay for gibberellins. Each chromatogram represents 250 mg dry weight. Ordinate represents increase in reducing sugars over 10⁻⁷ gram of GA per liter (0.38 mg/vial). (Native reducing sugars of each R_F fraction, tested without barley seed, were considered as controls.) Data obtained from one experiment; five other experiments yielded similar results.