The global cycle of methane

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VOGELS, G. D. 1979. The global cycle of methane. Antonie van Leeuwenhoek **45**: 347–352

Anaerobic degradation of organic material proceeds in four consecutive phases (Fig. 1). Polymers are hydrolyzed to monomers, which are fermented to various products. In the acetogenic or hydrogenic phase (Bryant and Wolin, 1975) these reduced products may be oxidized to acetate, formate and carbon dioxide, with hydrogen being formed as electron sink. The latter compounds are the substrates of methanogenic bacteria, which allow the hydrogenic metabolism to proceed by removing the product (H_2) of the equilibrium reactions.

Methanogenesis is optimal in anaerobic ecosystems supplied with large amounts of organic substrates. The contribution of these ecosystems to the atmospheric cycle of methane depends on the direct and open contact with the air. As shown in Fig. 2, most (90 %) of the atmospheric methane originates from ecosystems where the methanogens stay between one meter above the surface of the earth (as in ruminants) and one meter below that (as in swamps and paddy fields). Though these ecosystems convert only a minor part of the products of photosynthesis, their contribution to the recycling of carbon should not be underestimated. On a molar basis about 5 percent of the carbon fixed by photosynthesis is converted to atmospheric methane. The methanogens in these ecosystems recycle even more of the carbon, since they use acetate as the preferred substrate in swamps, paddy fields and muds of fresh water (Jeris and McCarthy, 1965; Smith and Mah, 1966; Cappenberg, 1974; Strayer and Tiedje, 1978). Apart from methane acetate is also converted to carbon dioxide.

Methane produced in sediments below a layer of about ten meters does not reach the atmosphere, but is converted to carbon dioxide by methane oxidizing bacteria (Koyama, 1963; Howard, Frea and Pfister, 1971; Ehhalt, 1974). Moreover anaerobic bacteria may be involved in the oxidation and cometabolism of methane in sediments (Davis and Yarbrough, 1966; Barnes and Goldberg, 1976; Reeburgh, 1976). In deep lakes and trenches in the ocean some anaerobic regions occur which are saturated with methane (Reeburgh, 1976). In such areas and in the sediments of the ocean methane-hydrates are formed, which are stable at

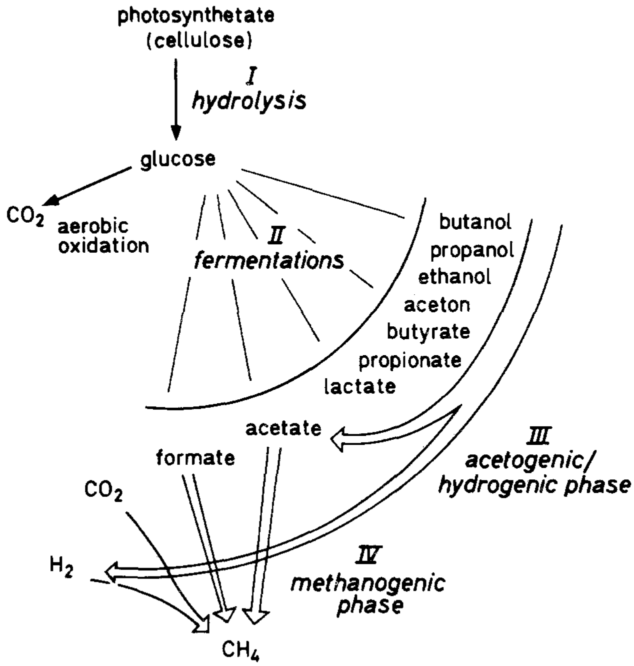

Fig. 1. Anaerobic degradation of organic material in four consecutive phases.

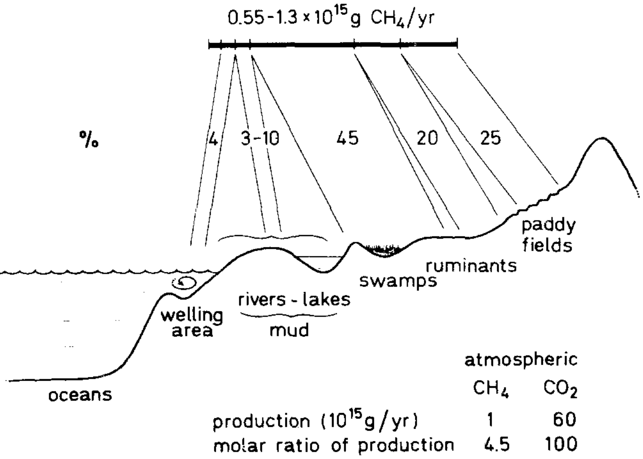

Fig. 2. Contribution of various anaerobic ecosystems to the atmospheric cycle of methane. The data are taken from Koyama (1963), Robinson and Robbins (1968), Lovelock (1971), Ehhalt (1974), Weinstock and Chang (1974) and Seiler (1977).

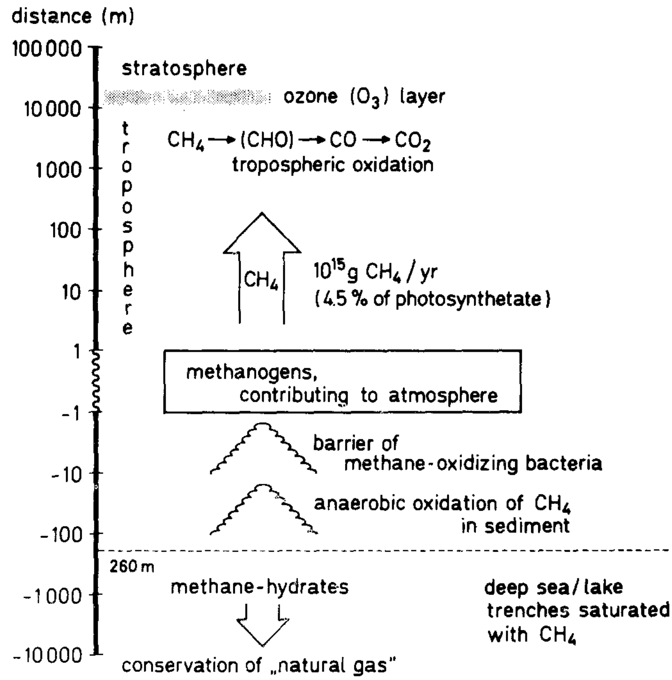

Fig. 3. Fate of methane produced by methanogens at various depths.

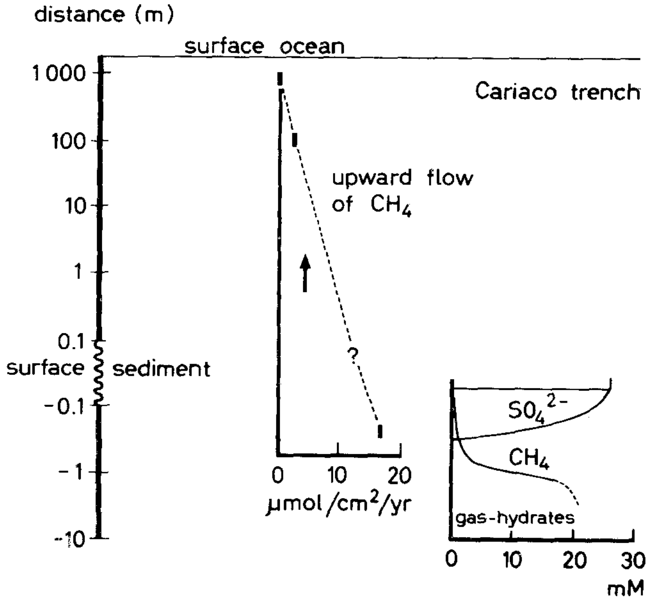

Fig. 4. Fate of methane produced in sediments of the Cariaco trench (Reeburgh, 1976).

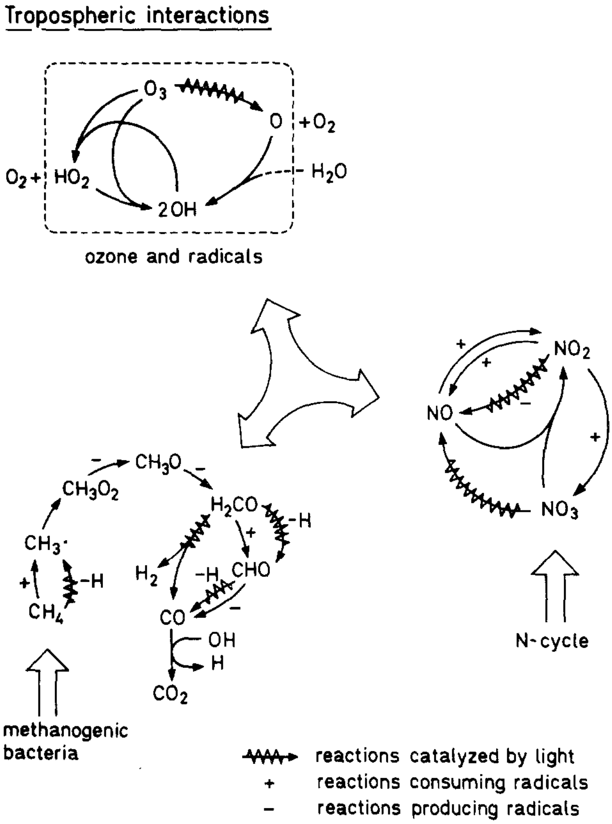

Fig. 5. Reactions involved in the tropospheric oxidation of methane. The data are partly taken from Ehhalt (1974) and Hubrich and Stuhl (1976).

pressures above 26 atmosphere, equivalent to a water layer of 260 meter (Kaplan, 1974). The presence of these methane-hydrates in the sediments of the ocean is apparent from acoustical measurements (Schubel and Schiemer, 1972; Claypool and Kaplan, 1974; Hampton and Anderson, 1974). High pressures do not affect methanogenesis (Koyama, 1963; Claypool and Kaplan, 1974). As a result of these processes only a minor part of the methane produced in nature reaches the atmosphere (Fig. 3). A recent report of Reeburgh (1976) illustrates this for a deap sea trench near Venezuela (Fig. 4). Methane produced in the sediments partly diffuses downward as methane-hydrates. Another part diffuses upward and is converted both under anaerobic and aerobic conditions; almost none of it reaches the atmosphere.

Methane molecules delivered to the atmosphere remain there for an average period of 1.5 to 7 years (Weinstock and Niki, 1972; Ehhalt, 1974, 1976). The major sink is present in the upper troposphere and lower stratosphere, where methane reacts with the intermediates and products of the ozone cycle (Fig. 5). So the methanogenic bacteria are the driving force for a number of cycles, and most of the atmospheric hydrogen, carbon monoxide and formaldehyde, and a substantial amount of stratospheric water is formed from methane (Weinstock and Niki, 1972; Ehhalt, 1974; Weinstock and Chang, 1974; Ehhalt and Volz, 1976).

Finally all methane is oxidized to carbon dioxide, so photosynthesis may proceed thanks to the action of methanogenic bacteria.

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