From marine photo-synthesis to petroleum

Bacterial degradation

A. Photosynthesis[1] by marine phytoplankton[2]
([1] application of energy in sunlight to chemical reduction of oxidized carbon (CO_2, HCO_3^-) to reduced organic form.
([2] e.g., dinoflagellates, diatoms)

B. (In modern ocean), bacterial aerobic oxidation in water column of most or all sinking remains of marine phytoplankton back to CO_2.

C. Bacterial aerobic oxidation of much organic material in uppermost centimeters of seafloor sediment back to CO_2.

D. Bacterial anaerobic oxidation of organic material in uppermost centimeters to meters of seafloor sediment, with N of NO_3^-, Fe^{3+}, Mn^{4+}, and S of SO_4^{2-} as electron acceptors.

0 +6 -2 +4

(e.g., $2CH_2O + SO_4^{2-} \rightarrow H_2S + 2HCO_3^-$)

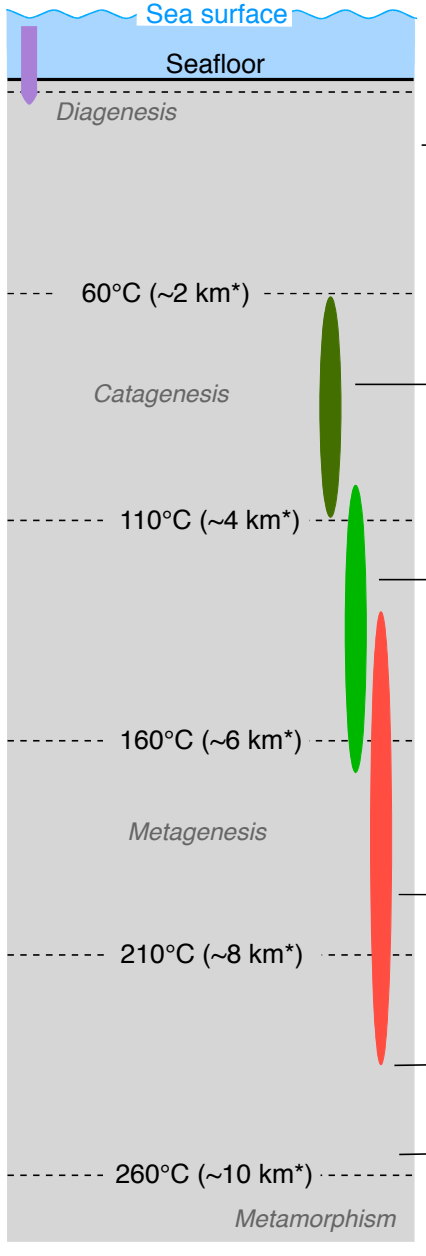
E. Bacterial anaerobic methanogenic degradation of organic material at a few meters depth in seafloor sediment.

0 -4 +4

($2CH_2O \rightarrow CH_4 + CO_2^{2-}$)

This methane has $\delta^{13}C$ of -50 to -90‰ relative to the PDB standard (cf. Part I).

F. In exceptional circumstances (see B to E above), survival of degraded organic material as kerogen in sediment progressively buried to greater depth by younger sediment.



F. In exceptional circumstances where the marine water column is anoxic and thus does not support aerobic oxidation, survival anaerobically degraded organic material as kerogen in sediment progressively buried to greater depth by younger sediment.

G. Maturation of kerogen (organic matter) sufficient to release molecules of many C atoms not unlike kerogen itself, and thus release of heavy oil.

H. Maturation of kerogen to release molecules of several (4-14?) C atoms and thus release of light oil.

I. Maturation of kerogen to release molecules of a few (1-4) C atoms and thus release of gas, especially methane (CH_4).
This methane has $\delta^{13}C$ of -20 to -55‰ relative to the PDB standard (cf. Part E).

Thermal maturation

J. Generation of methane from breakdown of oil still residing in source rocks or in deep reservoirs.

K. Further progression of kerogen toward graphite.

Sources: Hunt (1979) pp. 131-146 and 372-377; Price (1983); Tissot & Welte (1984) p. 199-211; Selley (1998) pp. 204-206 and 215-218; Gluyas & Swarbrick (2004) pp. 8-10 and 97; Bjørlykke (2010) pp. 341-343.

*The depths shown assume a geothermal gradient of 25°C/km.

The three main points of this document are

- 1) the organic matter from which petroleum is generated by thermal maturation has much earlier undergone extensive microbial degradation.
- 2) Generation of petroleum occurs in temperature-dependent (and perhaps to a lesser extent time-dependent) steps.
- 3) There are at least three phases in the history of organic matter at which methane can generated (see E, I, and J).

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