



Organic-inorganic interactions at oil-water contacts: quantitative retracing of processes controlling the CO₂ occurrence in Norwegian oil reservoirs

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Crude oil quality in reservoirs can be modified by degradation processes at oil-water contacts (OWC). Mineral phase assemblages, composition of coexisting pore water, and type and amount of hydrocarbon degradation products (HDP) are controlling factors in complex hydrogeochemical processes in hydrocarbon-bearing siliciclastic reservoirs, which have undergone different degrees of biodegradation. Moreover, the composition of coexisting gas (particularly CO₂ partial pressure) results from different pathways of hydrogeochemical equilibration.

In a first step we analysed recent and palaeo-OWCs in the Heidrun field. Anaerobic decomposition of oil components at the OWC resulted in the release of methane and carbon dioxide and subsequent dissolution of feldspars (anorthite and adularia) leading to the formation of secondary kaolinite and carbonate phases. Less intensively degraded hydrocarbons co-occur with calcite, whereas strongly degraded hydrocarbons co-occur with solid solution carbonate phase (siderite, magnesite, calcite) enriched in 13C.

To test such processes quantitatively in a second step, CO₂ equilibria and mass transfers induced by organic-inorganic interactions have been hydrogeochemically modelled in different semi-generic scenarios with data from the Norwegian continental shelf (acc. Smith & Ehrenberg 1989). The model is based on chemical thermodynamics and includes irreversible reactions representing hydrolytic disproportionation of hydrocarbons according to Seewald's (2006) overall reaction (1a) which is additionally applied in our modelling work in an extended form including acetic acid (1b):

- (1) R-CH₂-CH₂-CH₃ + 4H₂O → R + 2CO₂ + CH₄ + 5H₂,
- (2) R-CH₂-CH₂-CH₃ + 4H₂O → R + 1.9CO₂ + 0.1CH₃COOH + 0.9CH₄ + 5H₂.

Equilibrating mineral assemblages (different feldspar types, quartz, kaolinite, calcite) are based on the observed primary reservoir composition at 72 °C. Modelled equilibration and coupled mass transfer were triggered by the addition and reaction of different amounts of HDP. Modelled CO₂ partial pressure values in a multicomponent gas phase equilibrated with K-feldspar, quartz, kaolinite, and calcite resemble measured data. Similar CO₂ contents result from acetic acid addition (eq. 1b). Equilibration with albite or anorthite reduces the release of CO₂ into the multicomponent gas phase dramatically, by 1 or 4 orders of magnitude compared with the equilibration with K-feldspar (van Berk et al., 2009).

Third and based on data by Ehrenberg & Jakobsen (2001), the effects of organic-inorganic interactions at OWCs in Brent Group reservoir sandstones from the Gullfaks Oilfield (offshore Norway) have been hydrogeochemically modelled. Observed local changes in mineral phase assemblage compositions (content of different feldspar types, kaolinite, carbonate) and CO₂ partial pressures are attributed to varying degrees of oil-biodegradation (up to more than 10 %; Horstadt et al. 1992). Modelling results are congruent with observations and indicate that (i) intense dissolution of anorthite, (ii) less intense dissolution of albite, (iii) minor dissolution of K-feldspar, (iv) intense precipitation of kaolinite and quartz, (v) less intense precipitation of carbonate, and (vi) formation of CO₂ partial pressures are driven by the release of HDP.

References

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