COMPOSITIONAL FRACTIONATION DURING EXPULSION OF PETROLEUM FROM SOURCE INTO CARRIER BEDS

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Introduction

Despite years of research, primary migration is still among the least understood processes operating in petroleum systems. Basically, it comprises the discharge of oil and gas from a source rock into adjacent higher permeable strata via the usually low permeability pore network by diffusion, a process termed expulsion. Expulsion has been demonstrated to have a major impact on the compositional fractionation between hydrocarbon-rich petroleum vs. asphaltene/resin-rich source bitumen (Mackenzie et al., 1983; Leythaeuser et al., 1988a, b). In this study, we investigate the effects of petroleum expulsion using five different scenarios of adjacent source rock – reservoir/carrier bed couplets. Hereby, we studied bulk properties and applied a variety of bio- and geomarker molecules to characterize thermal maturation and selective retention of compounds in the source rock upon expulsion. Source and carrier rock couplets used to establish expulsion gradients comprise organic-rich shales from the Upper Jurassic Draupne Formation or coals from the Hugin Formation and adjacent sandstones preferably from the Hugin Formation. Sampling concentrated on intervals where organic-rich shales are interbedded with oil-wet sandstones, allowing for the reconstruction of expulsion gradients. The five expulsion scenarios of different dimension studied include, i) a thin (35 cm) source interval sandwiched between two sandstone carrier beds, ii) a 6 m source interval with an intercalated 1 m sandstone carrier bed, iii) a 50 m source bed overlain by 40 m of sandstone carrier bed; iv) a 60 m sequence of alternating source and carrier beds, and v) a sequence containing two coaly and one shaly source intervals alternating with carrier bed sandstones.

Results

Our preliminary data from scenario i) indicate the rich source potential (8 – 10 % TOC) and maturity within the oil window leading to generation and expulsion of oils (Fig. 1) as seen by TOC-normalized bitumen yields of 65 to 120 mg/gTOC. The bitumen yield shows a bell-shaped trend, with lowest bitumen yield in the centre of the source rock, its concentration increasing towards the edges because of petroleum expulsion. Not only the bulk oil increases towards the source rock rims but also compositional changes occur, which are related to interaction of bitumen released by generation with the pore surface. The amount of normal vs. isoprenoid alkanes (nC_{17}/Pr-ratio) increases towards the source rock edges, indicating the faster expulsion of n-alkanes. When alkane mixtures have been expelled into the carrier bed, the ratio inverts with isoprenoid preferentially retained on the carrier bed mineral matrix whereas n-alkanes get transported away by secondary migration. A similar trend was observed for the C_2 dibenzothiophenes vs. C_2 phenanthrenes (C_2 DBT/C_2 Phen) ratio. Polar C_2 DBTs are retained in the source, whereas less polar C_2 Phen are expelled into the adjacent carrier beds. We currently extend the database by analysis of another 60 samples for molecular data for scenarios ii) to v) to synthesize the effect of expulsion on bulk and molecular properties, depending on the interplay between source and carrier bed properties.

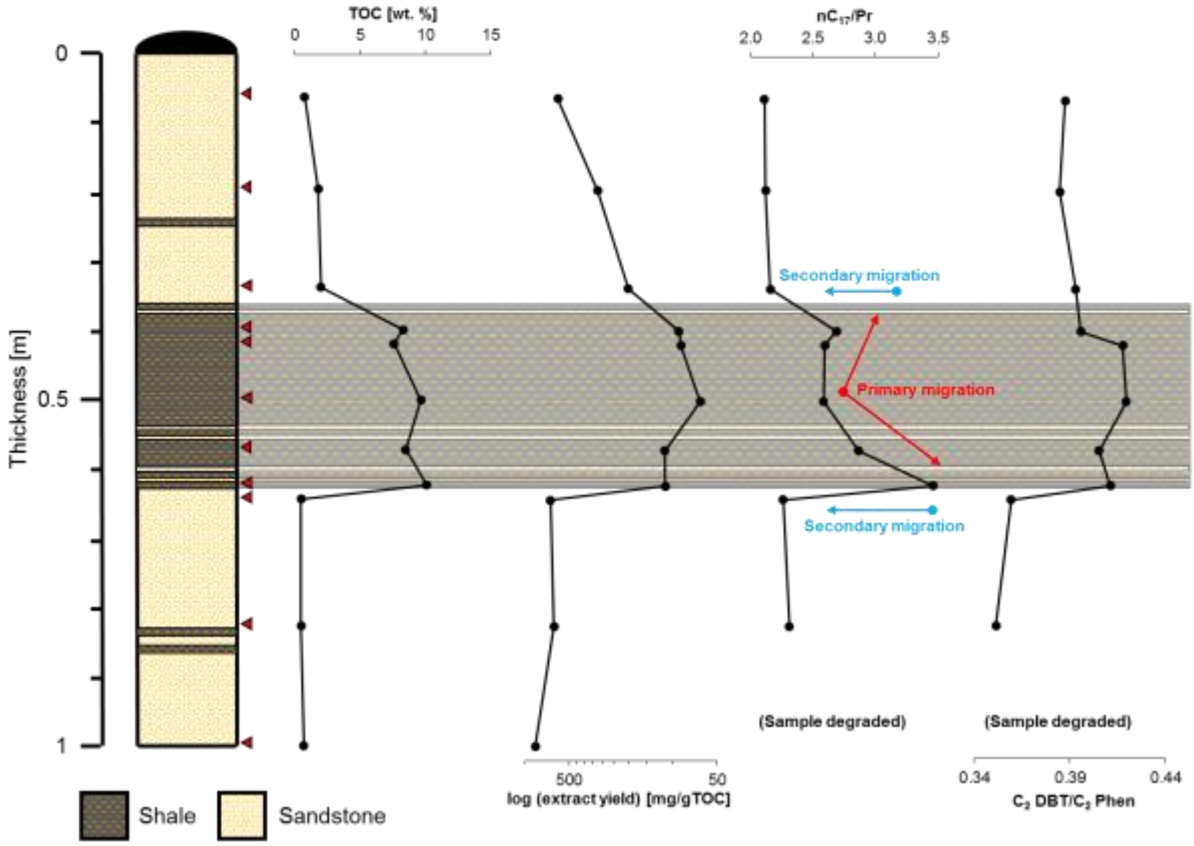

Figure 1: *Scenario i) representing an actively generating source rock sandwiched between two sandstone carrier bed lithologies. Shown are the Total Organic Carbon (TOC) content [wt. %], the normalized bitumen yield [mg/gTOC], the nC_{17}/Pristane (nC_{17}/Pr) ratio and the C_2 Dibenzothiophene/C_2 Phenanthrene (C_2 DBT/C_2 Phen) ratio. Note that normalized extract yields increase significantly towards the sandstones, pointing to active petroleum expulsion. nC_{17}/Pr increases towards the shale edges, followed by a remarkable drop within the sandstone intervals, indicating faster expulsion of nC_{17} relative to pristane within the source unit and subsequent loss of nC_{17} due to secondary migration in the carrier bed. The C_2 DBT/C_2 Phen plot suggests preferential retention of more polar dibenzothiophenes over phenanthrenes within the source unit upon expulsion.*

Conclusions

We postulate that *in situ* oil generation, expulsion and subsequent secondary migration have significantly altered the spatial distribution and composition of petroleum found in a source unit vs. two adjacent sandstone carrier intervals. The influence of source rock vs. carrier bed volumes/distance and the type of source (marine type II vs. humic type III kerogen) will be interpreted from investigation scenarios ii) to v). Analysis of compound classes more polar than thioaromatics will include alkylated carbazoles and benzocarbazoles, with the aim to differentiate the impact of primary vs. secondary migration on these geotracers.

References

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