‘Maturity contradictions’: Migration-contamination in crude oil

By Laura Garner

Geochemical profiling of petroleum has become an invaluable tool in the appraisal of source rock age, maturity, lithology and depositional setting. This assessment inherently assumes that the molecular signature of the source rock will be reflected in the expelled oil, however we quite commonly observe unusual biomarker compositions in the trapped fluids that cannot be explained by source facies/maturity variation, fluid mixing or in-reservoir alteration (e.g. biodegradation). In such cases, anomalies in the biomarker distribution of the fluids may be attributed to major processes that occur during oil migration from source to reservoir such as migration fractionation and migration-contamination, the latter of which will be the subject of this technical note.

Migration-contamination (also known as solvent-stripping, leaching, reservoir overprinting and solubilization) is a process whereby the oil acts as a solvent for non-source molecular components from syndepositional organic matter of the migration conduit and/or reservoir rock (Curiale, 2002; Gallegos, 1981) (Fig.1). The extent of contamination is heavily dependent upon the contact time between the oil and the non-source rock organic matter and upon a good quality carrier structure. In addition, the process of leaching is more likely to occur where reservoirs or migration pathways contain organic-rich interbedded rocks of relatively low thermal maturity. Solubilization can be particularly important when interpreting condensates (which are inherently biomarker-poor) migrating through organic-rich intervals (Peters *et al.*, 2005) or reservoired in rocks with coal/shale interbeds or dispersed organic matter.

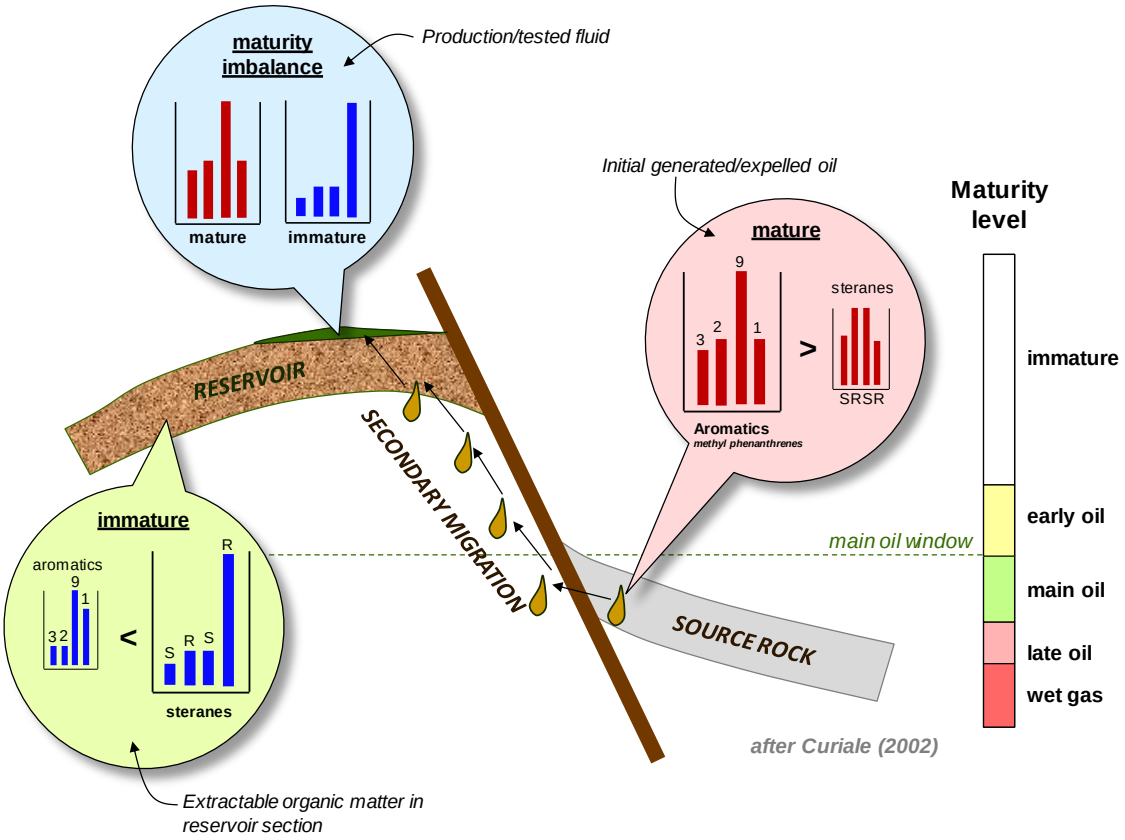

Figure 1: The formation of maturity imbalance caused by migration-contamination (modified from Curiale, 2002).

The most widely recognised indicators of migration-induced, or in-reservoir contamination of a crude oil are olefins (unsaturated hydrocarbons-alkenes) and carboxylic acids (non-hydrocarbon compounds); and yet these molecular constituents are not commonly used in geochemical interpretations due to analytical difficulties and their low concentrations in 'typical' oils. Aside from the use of olefins and carboxylic acids, regular saturated and aromatic hydrocarbons can also be used to assess migration-contamination effects, typically through contradictory thermal maturity signals evident within the same crude oil. This has been shown for example by Philp & Gilbert (1982) who suggested that the non-equilibrium distribution of 22R & 22S isomers of the homohopanes in some Gippsland Basin oils were a result of the expelled oil encountering immature coal zones interbedded in the reservoir units upon migration.

A good example of the recognition of leaching from maturity contradictions is shown by fluids from the Hod and Valhall Fields in the North Sea. These oils have an unusually low sterane maturity signal *($C_{29}ααaR > C_{29}ααaS$ & C29αββ 20R+S < C29ααα 20R+S)* (Fig. 2) when compared to other fields in the region, suggesting leaching of immature biomarkers on the migration path.

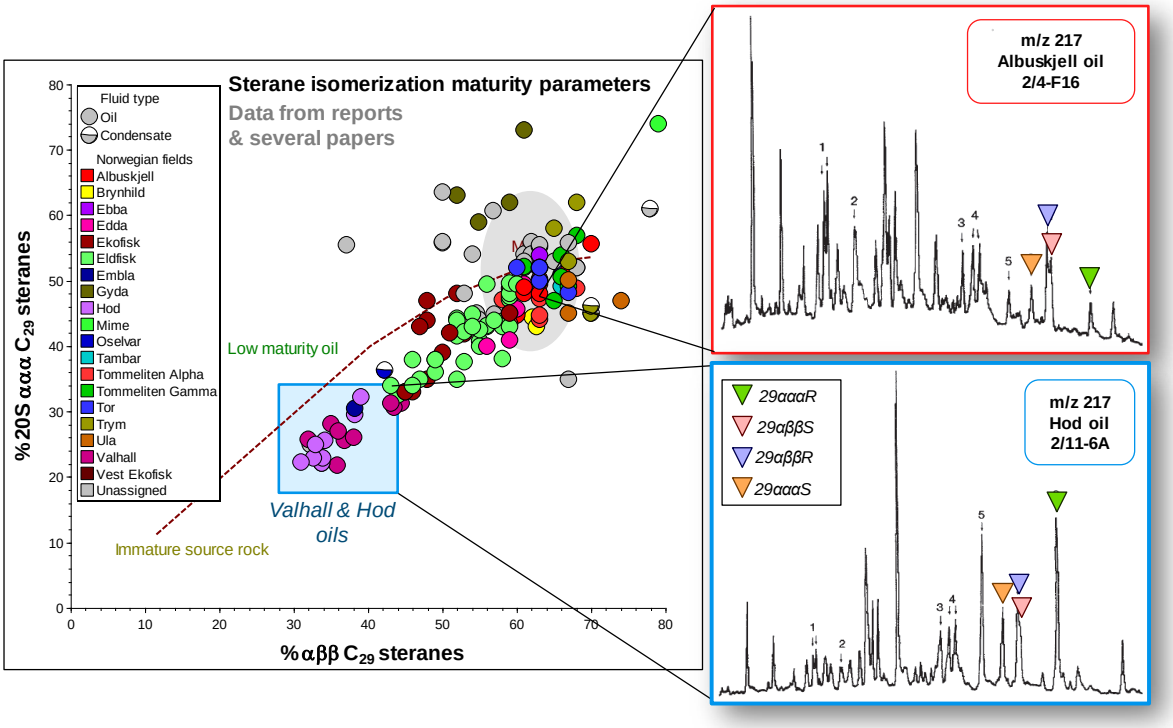

Figure 2: Example of leaching affecting the Valhall & Hod fields, North Sea (chromatograms adapted from Hughes *et al*., 1985).

Notably, this apparent low maturity in the steranes is not evident in the aromatics (Fig. 3), which show normal oil window maturity. This is due to the differences in relative concentrations of biomarkers and aromatic hydrocarbons in the migrating oil and the non-source organic matter that it is leaching, oils tending to be generally richer in aromatics and leaner in biomarkers than less mature sedimentary organic matter. This means that in oils suspected to have suffered leaching, the aromatics likely provide a more reliable maturity estimate than

the saturated hydrocarbons. In addition to the aromatics, bulk parameters and abundant components such as *n*-alkanes and acyclic isoprenoids are also likely to be less affected by overprinting (Peters & Fowler, 2002). In fact, in cases where the biomarkers are overprinted and cannot be reliably used in oil-oil and oil-source correlation, the bulk fraction stable carbon isotopes can be used successfully.

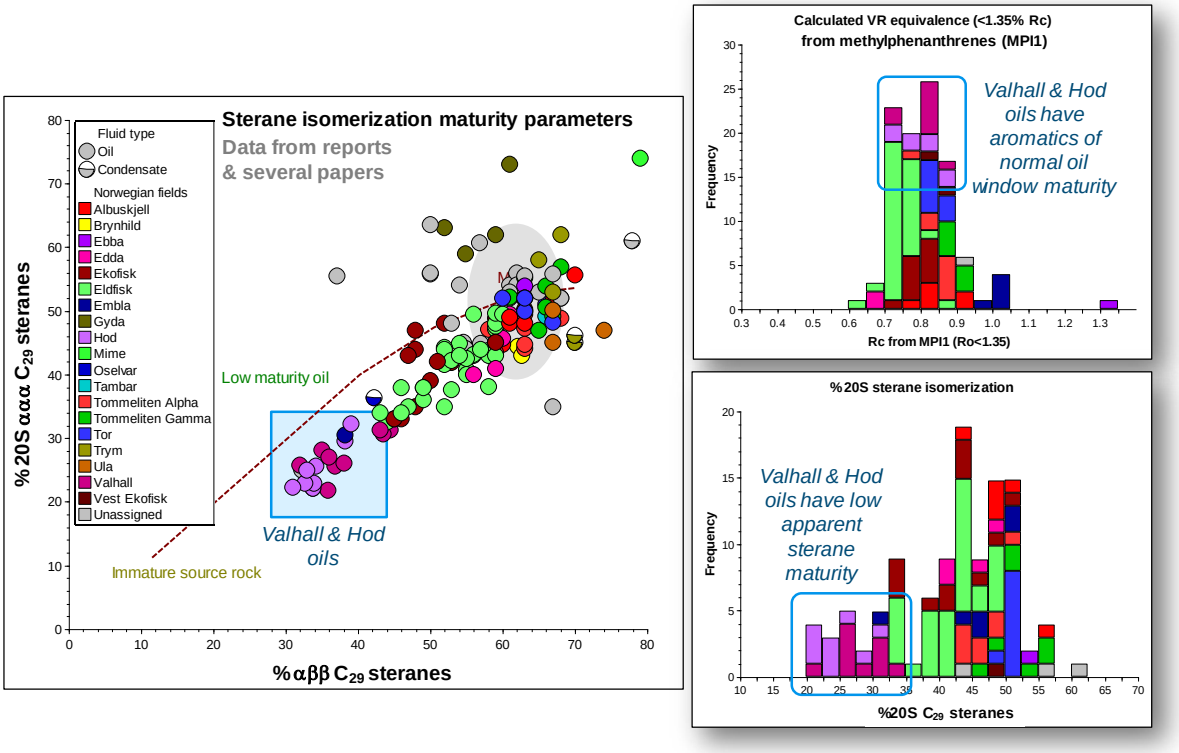

Figure 3: Comparison of saturated and aromatic maturity parameters of the Valhall & Hod oils.

It is also important to note that organic matter present in a migration pathway or reservoir that is more enriched in steranes (marine depositional environment) or hopanes (more terrestrially dominated) may preferentially overprint one type of biomarker class (depending also on their concentrations within the migrated oil), with either the steranes or hopanes appearing of lower maturity than the other.

Leaching is likely a very common occurrence in petroleum systems but may often go unrecognized. It is generally most obvious for lighter oils and condensates, which can have their low biomarker concentrations easily overprinted by immature biomarkers during migration or in-situ in the reservoir. This emphasises the importance of using multiple geochemical parameters to assess maturity to attain a more reliable estimation of fluid maturity and source.

References:

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