

**‘Smart Water’ as wettability modifier  
in carbonate and sandstone:  
A discussion of similarities in the  
chemical mechanisms**

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Waterflooding has for a long time been regarded as a secondary oil recovery method. In the recent years, extensive research on crude oil, brine, rock (COBR) systems has documented that the composition of the injected water can change wetting properties of the reservoir during a waterflood in a favorable way to improve oil recovery. Thus, injection of ‘Smart Water’ with a correct composition and salinity can act as a tertiary recovery method. Economically, it is, however, important to perform a water flood at an optimum condition in a secondary process. Examples of ‘Smart Water’ injection in carbonates and sandstones are:

1. Injection of seawater into high temperature chalk reservoirs
2. Low Salinity floods in sandstone reservoirs

The chemical mechanism behind the wettability alteration promoted by the injected water has been a topic for discussion both in carbonates and especially in sandstones. In this paper, the suggested mechanisms for the wettability modification in the two types of reservoir rocks are shortly reviewed with a special focus on possible chemical similarities. The different chemical bonding mechanisms of polar components from the crude oil onto the positively charged carbonate and the negatively charged quartz/clay indicates a different chemical mechanism for wettability modification by “Smart Water” in the two cases.

[1] Doust *et al.* (2009) Paper presented at: *The 15<sup>th</sup> European Symposium on IOR*, Paris 27-29 April.

**Trace element and Pb and Sr isotope  
systematics in petroleum systems**

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The presence of trace metals in crude oils can cause severe problems in refineries as they may pollute the catalysts. However, relative and absolute concentrations of metals can provide further insights into source rock characteristics and have been used for oil-oil/oil-source correlations. To date, most studies have focused on Ni and V which are primarily present as metalloporphyrins which reside in the heavier organic fractions of the oil. The presence of other trace elements in petroleum studies is well understood, but considerable fractions might be entrained in the crudes as salts/brines, formation waters and/or mineral matter. Radiogenic isotope systematics (Sm-Nd and Re-Os isotopes) have also been used in the field of oil-source correlations and for dating of hydrocarbon accumulations.

In the current study a large number of trace elements and Sr and Pb isotopes were analysed in a selection of crude oils/condensates of variable maturity and degree of biodegradation, from several petroleum systems around the world. The oils were ashed in pressurised quartz vessels in a High Pressure Asher (HPA) system. Sr and Pb isotopes were measured by TIMS and MC-ICPMS, respectively, and trace element abundances by ICP-MS. Good accuracy and precision was obtained for V, Cr, Ni, Cu, Co, As, Rb, Sr, Ba, Pb, Mo, Th, U, Zr as inferred from replicate analyses of international oil and coal standards.

Most of the trace metals show negative correlations with API gravity, which may extend the use of metals in oils as potential correlation and classification tool beyond Ni and V. Pb and Sr isotope compositions of the oils are variable, even amongst oils from the same petroleum system, and show no obvious relation to provenance or age of the oils. The similarity between isotope ratios of a crude oil and its related formation water, but also between whole oils and acid leachates, poses the question of which phases contribute to the Sr and Pb isotope systematics of the oils. This will be discussed in more detail.