

## Lack of biodegradation in some cool shallow oilfields: Palaeopasteurisation

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Biodegraded oils are common in cool (<80°C) shallow reservoirs, but in some parts of the world such reservoirs can contain non-degraded petroleum. These cases of undegraded oil in shallow reservoirs typically either represent very recent (or ongoing) hydrocarbon charging, or more interestingly, occur in reservoirs that have been significantly uplifted from previously deeper, hotter conditions.

Twenty years ago, we published a paper presenting the concept of palaeopasteurisation to explain why non-degraded oil could be found in such uplifted reservoirs currently situated in cool shallow conditions (Wilhelms *et al.*, 2001). This concept (Figure 1) proposes that petroleum reservoirs are sterilised (pasteurised) by burial to depths where temperatures exceed around 80°C – the temperature threshold that is widely accepted as the limit to which common hydrocarbon-degrading microbes can exist. If oil subsequently charges the sterilised reservoir, even if it has been uplifted to cooler conditions, it will not be degraded due to an absence of hydrocarbon-degrading organisms. This, of course, implies that the reservoirs are not recolonised by microbes that can degrade oil.

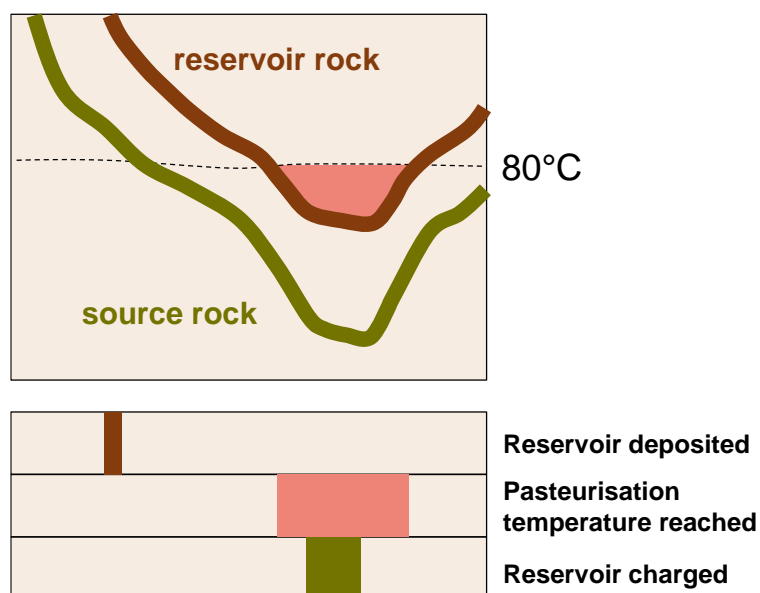
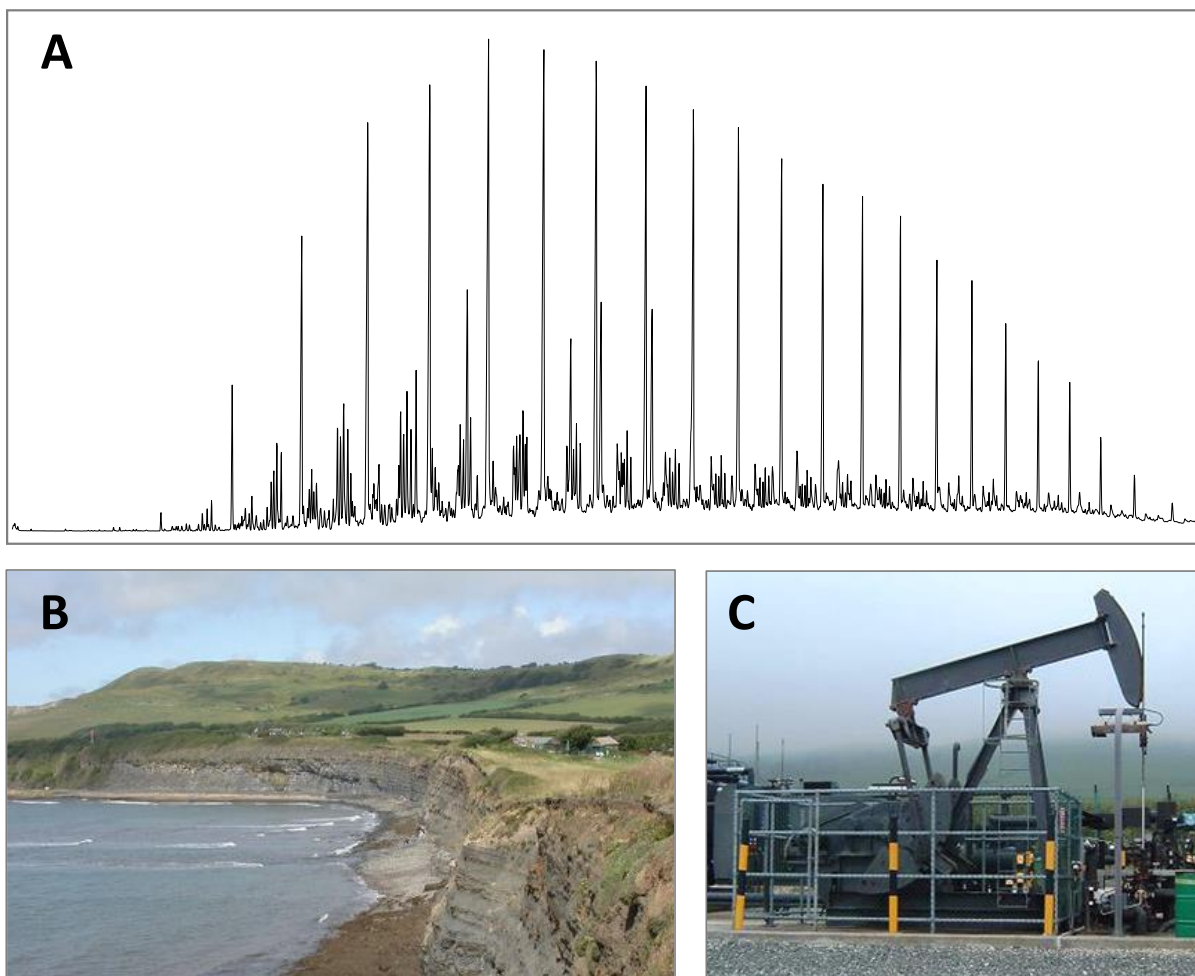


Figure 1: A schematic burial history of the reservoir & source rock in an uplifted basin (top) with petroleum system events (below); modified from Wilhelms *et al.* (2001). In this example the oil entered the reservoir after burial to greater than 80°C and the oil is not degraded due to the sterilisation of the reservoir, even after subsequent uplift to cooler and shallower conditions.

**Case example (Kimmeridge Bay):** Wilhelms *et al.* (2001) indicated several areas where non-degraded oil occurs in shallow uplifted (palaeopasteurised) reservoirs, presenting data from examples in the Norwegian Barents Sea and the Wessex Basin in the United Kingdom. The oil in the small oilfield at Kimmeridge Bay (Wessex Basin, Dorset, UK) shows no evidence for biodegradation yet it lies just 525m below the surface at a present day temperature of less than 40°C (Figure 2). Basin modelling (e.g., Bray *et al.*, 1998) indicates that the reservoir (Cornbrash Formation) was much more deeply buried prior to the Alpine Orogeny, experiencing extensive uplift associated with the basin inversion during the Tertiary (possibly ca. 40-15Ma ago). The reservoir was initially buried to temperatures in excess of 80°C about 50Ma ago, at around the same time as the Lower Jurassic (Lias) source rocks were entering the oil window (Bray *et al.*, 1998). Oil was generated and entered the sterilised reservoir, so that even after subsequent uplift of over 2000 meters no biodegradation has been experienced by the oil. This is a clear example of the apparent difficulty of recolonisation of reservoirs by hydrocarbon-degrading microbes, as the reservoir sits only 525m below the surface at present day. This in turn suggests that the microbes that normally degrade oils in subsurface reservoirs are not introduced by groundwater but are descendants of the bacteria and archaea that were buried with the original sediment!



**Figure 2: (A)** A gas chromatogram of the oil from the Kimmeridge oilfield, showing a full series of *n*-alkanes (the regular series of dominant peaks) with no evidence of biodegradation; the produced oil is light with an API gravity of 45°. **(B)** A view of the cliff section at Kimmeridge Bay with the oilfield on the cliff top in the middle of the picture above the broad anticlinal structure. **(C)** The nodding donkey at Kimmeridge.

In hydrocarbon exploration, cool shallow prospects should not be discounted on the grounds of high biodegradation risk unless the potential for palaeopasteurisation has been considered. Basin models can provide a reservoir temperature history and will also constrain the timing of source rock maturation, hydrocarbon generation and charging of the structure. Consideration of all these factors may, at least in uplifted basins, highlight shallow prospects with the potential for oil charge after the reservoir has been pasteurised, with consequent preservation of undegraded oil.

## References

- Bray, R.J., Duddy, I.R. & Green, P.F. (1998). Multiple heating episodes in the Wessex Basin: implications for geological evolution and hydrocarbon generation. In: *Development, Evolution and Petroleum Geology of the Wessex Basin* (eds: Underhill J. R. *et al.*), Geol. Soc. London Spec. Pub. **133**, 199-213.
- Wilhelms, A., Larter, S.R., Head, I., Farrimond, P., di Primio, R. & Zwach, C. (2001). Biodegradation of oil in uplifted basins prevented by deep-burial sterilization. *Nature* **411**, 1034-1037.