DETERMINING THE CHARGE / RECHARGE HISTORY OF BIODEGRADED OIL RESERVOIRS

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Summary: Many oil accumulations are the result of charges to the reservoir that have been biodegraded to different extents. Such mixed oils arise from up to several episodes of charging, biodegradation, recharging, biodegradation, and so on. A new method to determine biodegradation rankings of oil has been developed based on analysis of biomarker carboxylic acids. This method can be used to identify multiple charging and recharging events (up to four events), determine the level of biodegradation experienced by the oil as a result of each episode of biodegradation, and provide a semi-quantitative method to evaluate the importance of each biodegraded charge to the overall oil accumulation.

Introduction: Petroleum biodegradation in reservoirs has been characterized by various geochemical scales. The objective has been to provide a method of ranking the degree of biodegradation of the oil. In the biodegradation ranking scale attributed to Peters and Moldowan (1993) (re: P&M Ranking Scale) a series of changes in the geochemical fingerprints of saturated and aromatic hydrocarbons that occurs progressively at greater and greater levels of biodegradation are used to rank the severity of the biodegradation on a scale of 0 – 10, where Rank 0 signifies non-biodegraded oil and Rank 10 signifies oil that is biodegraded to extreme severity. The P&M Ranking Scale is based, primarily on the disappearance of n-alkanes and biomarkers that have been observed to be progressively more and more recalcitrant to conditions of biodegradation in the reservoir. Only one class of saturate biomarkers, the series of 25-norhopanes, stands alone, and is widely accepted to appear (at about Rank 6) and become more concentrated during advanced biodegradation, while the putative precursors of these compounds, the series of 17α-hopanes, decrease at higher biodegradation ranks. However, this simple P&M Ranking Scale is often not exactly followed in practice, and in particular it is often observed that 25-norhopanes are present in oil that also shows abundant n-alkanes and isoprenoids, compounds that should have long been removed at less-severe levels of biodegradation (i.e., Ranks 1-5). Geochemical interpreters often attribute such situations as an indication of heavy biodegradation of an initial oil charge followed by reservoir re-charge with non-biodegraded oil. The recharge-oil may itself undergo biodegradation, as well, showing a higher final P&M Rank.

Results and discussion: We hereby present a method to evaluate biodegradation ranking based on biomarker acids in oils. The ranking scale based on the biomarker acids can be correlated with the P&M Ranking Scale allowing oil samples to be ranked in the same way. This has been accomplished by using some of the same oils that were originally used to calibrate and create the P&M Ranking Scale. These oil samples are from fields in the San Joaquin Valley (SJV), California, USA, and, for the most part, they do not display indications of mixed levels of biodegradation. By using this calibration set is was realized that several carboxylic acid series appear and disappear at different P&M Ranks providing the opportunity to identify multiple re-charge events and the approximate P&M Rank of the oil remaining from each event.

The results in Figure 1 show the occurrence of biomarker acids in the set of SJV oils that span the P&M Ranks 0-9. In this set of samples it is shown that six series of biomarker acids appear and disappear as different stages of biodegradation severity are reached. Thus, n-alkanoic and phytanoic acids occur only in non-biodegraded oils and lightly biodegraded oils (P&M Ranks 0-3), tricyclic terpanoic and ββ-hopanoic acids occur only in moderately to heavily degraded oils (P&M Ranks 5-6), and 25-norhopanoic acids occur only in severely biodegraded oils (P&M Ranks 8-9).

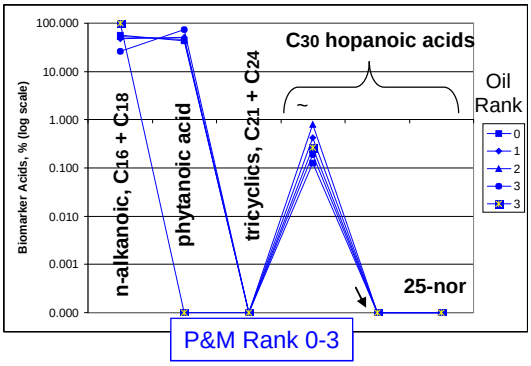
Using this calibration set we have evaluated exemplary biodegraded oil samples from various basins of the world to show their biodegradation history and determine the relative importance of each component of the mix according to the biodegradation ranking of the component. The number of charge and re-charge events (up to four events) can be determined by combining data from the biomarker acids and saturate biomarkers analyses, and the relative importance in terms of oil quantity of each event can be estimated.

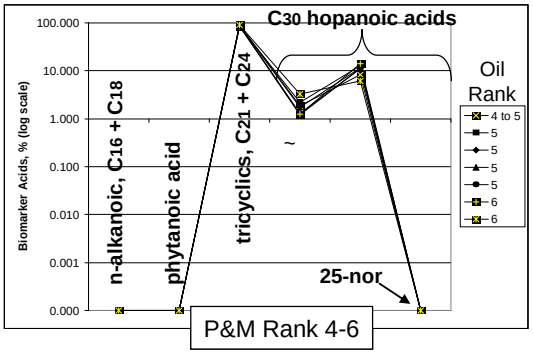
References:

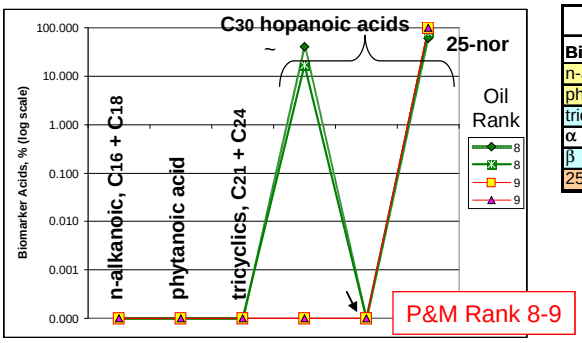
K. E. Peters and J. M. Moldowan (1993) The Biomarker Guide. Prentice-Hall. 363 pages.

Z. Chen (2005) Ph.D. Dissertation. Department of Geological and Environmental Sciences, Stanford University.

Figure 1. Biomarker acids distributions in related San Joaquin Valley oils with a range of in-reservoir biodegradation rankings indicated. Evidence suggests they are singly sourced biodegraded oils without obvious recharge effects.







Biomarker Acids Biodegradation Summary for S. J. V. Oils	
Biomarker acid compounds	**P&M Rank of Occurrence**
n-alkanoic	0 to 3
phytanoic	0 to 3
tricyclic terpanoic	5 to 6
α β hopanoic	0 to 8
β β hopanoic	5 to 6
25-norhopanoic	8 to 9

P&M biodegradation levels were assigned using the ranking scale of Peters and Moldowan (1993).

Data from Z. Chen (2005).