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Fluid Inclusion Evidence for Alteration of Crude Oils

Petroleum alteration processes can be recognized, characterized and mapped using a combination of mass spectrometric analysis of fluid inclusion volatiles (Fluid Inclusion Stratigraphy or FIS), fluid inclusion biomarker analysis and classical fluid inclusion petrography and microthermometry. Diagnostic criteria have been developed to recognize biodegradation, water-washing, thermal alteration (including TSR) and solid bitumen precipitation mechanisms. Characterization of biodegradation is the subject of this presentation.

Biodegraded petroleum inclusions display a distinctive chemical suite of FIS volatiles, including elevated CO_2, biogenic methane, aromatics, organic acids and sulfur compounds (H_2S, COS, CS_2, S_2 +/- SO_2 and thiols). Additionally, ratios of alkanes to cycloalkanes are typically low, depending on the extent of degradation. Biodegraded oil inclusions tend to be poorly formed, have variable liquid/vapor ratios and low measured API gravities. GCMS data reveal the same chemical indicators of bacterial alteration observed in classical whole-oil biomarker analyses, including reduction of n-alkanes at incipient degrees of alteration and appearance of demethylated hopanes at high degrees of alteration. Data are most consistent with alteration by thermophilic, sulfate-reducing anaerobes at temperatures below 60-808C.

FIS microseeps are identified above approximately 75-80% of deep productive reservoirs, and are thought to arise through near-vertical microseepage of light hydrocarbons accompanied by redox reactions at depth-temperature-nutrient conditions permissible for bacterial activity. These features are identified upper 1-1.5 km of rock column in areas with high geothermal gradients, but significantly deeper in areas with low heat flow. Species include light hydrocarbons (generally C1-C5) as well as the compounds mentioned above for biodegraded ‘continuous-phase’ petroleum occurrences.