PETROLEUM GEOCHEMISTRY, SOURCE ROCK EVALUATION AND MODELLING OF HYDROCARBON GENERATION IN THE SOUTHERN TAROOM TROUGH

WITH PARTICULAR REFERENCE TO THE TRIASSIC SNAKE CREEK MUDSTONE

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ABSTRACT

Whether or not Triassic source rocks have contributed to the known petroleum reserves of the Bowen and Surat Basins is still unknown. In order to assess the relative contributions of Triassic and Permian hydrocarbons, a comprehensive geochemical study was made of oils and potential source rocks from the southern Taroom Trough. The study employed total organic carbon, Rock-Eval pyrolysis, organic petrography, extractable bitumen, biomarker and isotopic analyses, the latter including compound-specific isotope analysis (CSIA) of individual *n*-alkanes in extracts, pyrolysates and oils. Petroleum generation was also modelled, using first-order reaction kinetics and the BasinMod program, in order to predict the timing and amount of hydrocarbon generation and to explain the observed distribution of oil *versus* gas in the petroleum systems of the Bowen and Surat Basins.

In the Taroom Trough, the major potential source rocks are marine mudstones in the lower part of the Permian section (Back Creek Group, BCG), and coals and carbonaceous shales in its upper part (Blackwater Group, BWG). Both Permian marine and nonmarine lithofacies are organic-rich and have attained sufficient maturity for oil and gas generation. However, using molecular and isotopic data, the major source of petroleum was shown to be the BWG. A previously unrecognised subsidiary source was identified - the Triassic Snake Creek Mudstone (SCM) - and this lacustrine unit became the focus of further detailed investigation. Two SCM lacustrine environments are distinguished by their diagnostic molecular fingerprints. An oxygenated freshwater setting was widely distributed across the southern Taroom Trough, whereas a brackish suboxic environment developed locally in different parts of the basin. Evidence of a marine influence on the Snake Creek palaeolake is confined to the northwest and southeast margins of the southern Taroom Trough.

Artificial and natural maturation of the Taroom Trough source rocks reveals that biomarker maturity parameters can be affected by variations in kerogen type as well as mineralogy. Whereas rearranged drimanes are a characteristic feature of argillaceous petroleum source rocks, abundant homodrimanes and methylhomodrimanes are a diagnostic peculiarity of calcareous mudstones deposited under less oxic, and probably more saline, conditions. A comparison of the relative abundance of 16α(H)- and 16β(H)-phyllocladane with other maturity data revealed a 'reversal' in the trend of increasing $\beta/(\alpha+\beta)$ values at maturities higher than those corresponding to the onset of oil generation. The present study sheds light on the previously undocumented behaviour of the phyllocladanes during the late stage of catagenesis. The proportion of 16β(H)-phyllocladane $\beta/(\alpha+\beta)$ increases quickly with increasing maturation to a maximum value of ~0.88 at about the oil generation threshold, and then declines steadily from 0.88 to 0.65 through the oil window, eventually attaining equilibrium at 0.6 within the zone of dry gas generation.

The Permo-Triassic sequence in the southern Taroom Trough attained its maximum palaeotemperatures during the Late Cretaceous as a result of deep burial (in the south), or a combination of Cretaceous (± Triassic) burial and a thermal episode (in the north). This differential uplift and erosion has resulted in different effective periods of maturation and thus different prospectivities along the basin. The SCM in the south entered the oil window in the latest Early Cretaceous, whereas the underlying Permian section started generating hydrocarbons during the Jurassic. These hydrocarbons migrated updip to the east and west where structural-stratigraphic traps had formed in response to Triassic compressional deformation. Kinetic modelling proved that the oil and gas currently produced from sandstone reservoirs were sourced mainly from the BWG, with a lesser contribution from the BCG. Although the contribution of hydrocarbons from the SCM source rock was minor, it was sufficient to form a second petroleum system. In the north of the study area, early (Triassic) generation of hydrocarbons and subsequent (Jurassic-Cretaceous) burial left an overmature Permian section, at present able to generate only dry gas. The bulk of its hydrocarbons have, most likely, migrated to the south and west where oil and gas currently are being produced. High prospectivity is indicated for the southern region where generation and migration of hydrocarbons (Jurassic-Cretaceous) post-dated trap formation (Triassic), whereas in the north the bulk of generated hydrocarbons were expelled before the main deformation. Therefore, the considerable volumes of hydrocarbons generated in the north must have been lost as no traps or seals were in place.

Two petroleum systems can be identified in the southern Taroom Trough. The Triassic 'SCM-Showgrounds' petroleum system involves Triassic source and reservoir rocks in a very localised area of the southwestern part of the trough. It encompasses Family 1 oils produced from the Roswin North, Rednook and Merroombile petroleum pools (reservoired in the Showgrounds Sandstone), and the SCM source rock in the vicinity of Inglestone-1 and the adjacent deeper parts of the trough where the unit has its highest hydrocarbon-generating potential and shows microscopic evidence of active hydrocarbon generation. Hydrous pyrolysis of SCM kerogens and CSIA of the SCM extracts and kerogen pyrolysates suggest that its expelled oils are derived primarily from free lipids, with a minor contribution by hydrocarbons released catagenetically from the kerogen. The Blackwater-Precipice petroleum system (Permian-sourced), on the other hand, is of wider areal and stratigraphic extent. It includes the source rocks of the Back Creek and Blackwater Groups, which are mature to overmature throughout much of the Taroom Trough, and all related Family 2 hydrocarbons produced from reservoirs of Permian to Jurassic age along the southeastern and southwestern margins of the trough.

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