GEOCHEMISTRY AND MICROTHERMOMETRY OF ~ 1400 MILLION YEAR-OLD OIL IN FLUID INCLUSIONS IN SEDIMENTARY AND IGNEOUS ROCKS IN THE ROPER SUPERBASIN, AUSTRALIA

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Introduction

Very little is known about the petroleum migration histories of Precambrian basins due to the destructive effects of metamorphism and deformation. Equally little is known about the composition of the early biosphere from which the organic source rocks formed. Here, we report preliminary geochemical and microthermometric analysis of oil trapped in fluid inclusions in a Middle Proterozoic sandstone and dolerite dyke. Our work is based on the ca. 1430 Ma Roper Group from the Roper Superbasin, northern Australia (Fig. 1). Sediments include an organic-rich source rock - the Velkerri Formation (George and Ahmed, 2002) and a sandstone reservoir- the Bessie Creek Formation. These are intruded by a 1280 Ma (McDougall, 1965) 92 m-thick dolerite dyke, which caused early maturation of the Velkerri Formation (George and Ahmed, 2002). The sequence was subjected to a structural Mesoproterozoic inversion episode which post-dates emplacement of the dolerite sill (Rawlings, 1999). The region has been stable since the inversion (Haines et al., 1999).

Methods

Samples of the dolerite sill and Bessie Creek Sandstone were collected from diamond drill cores from the Borrowdale-2 and Friendship-1 wells (Fig. 1). A dozen doubly-polished sections was examined by an optical microscope equipped epifluorescent light. Microthermometry of 430 coeval oil and aqueous in the sandstone and 183 coeval oil and aqueous inclusions in the dolerite was carried out on a Linkham heating-freezing stage. Determination of the molecular composition of oil inclusions was carried out at CSIRO in Sydney using the off-line crushing method described in detail in George et al. (2001) and references therein. The extracted fluid inclusion oils were analysed by gas chromatography-mass spectrometry on a Hewlett Packard 5890 gas chromatograph attached to a VG AutoSpecQ Ultima mass spectrometer.

Results

The Bessie Creek Sandstone is a quartz arenite with no visible porosity. It contains pervasive syntaxial overgrowths and triple junctions between grains formed during emplacement of the overlying dolerite sill. Abundant, 10 μm-long, blue fluorescing oil inclusions occur in transgranular fractures which cut across the diagenetic and contact metamorphic fabric. Homogenisation temperatures (T_H) of coeval oil and aqueous inclusions fall in the range 40°C to 110°C. Modes of T_H of thermometrically coherent assemblages fall within a narrow range of 48 ± 9°C to 60 ± 5°C making T_H modes of aqueous and oil inclusion in any one trail statistically indistinguishable. Oil inclusions in the dolerite sill are < 10 μm-long and fluoresce blue and yellow. They occur as trails within microfractures and as clusters in feldspar related to alteration zones within the cleavage planes. Abundant oil inclusions also occur within microfractures in a calcite vein which cuts the dolerite dyke (George et al., 1994). Homogenisation temperatures of these inclusions are slightly higher than in the Bessie Creek Sandstone ranging from about 40°C to 140°C for the oil inclusions in the calcite, 75°C to 135°C for the coeval aqueous inclusions in the calcite, and 56°C to 127°C for oil inclusions in alteration zones in the feldspar. The higher homogenisation temperatures may reflect stretching/leakage of inclusions in a soft mineral host.

Both fluid inclusion oils (FIOs) contain C_5 to C_{32} *n*-alkanes. The relative abundances of *n*-alkylcyclohexanes and methylalkylcyclohexanes are high in both FIOs, while isoprenoids are present in very low abundance. Monomethylalkanes are abundant in the Bessie Creek Sandstone FIO, but are less abundant in the dolerite FIO. The high monomethylalkane content indicates a source rock containing abundant organic matter from cyanobacteria. Pentacyclic triterpanes are present in both the FIOs, with distributions typical of mature oils. Hopane maturity parameters such as Ts/Tm suggest that the high molecular weight fraction in the Bessie Creek Sandstone FIO has a higher thermal maturity than this fraction in the dolerite FIO, and this is corroborated by aromatic hydrocarbon maturity-sensitive ratios. However, C_5 to C_9 hydrocarbons in the dolerite FIO are very abundant and have a distribution consistent with generation in the peak to late oil window maturity.

Interpretation

The inclusions were most likely trapped during Mesoproterozoic basin inversion, soon after the emplacement of the dolerite dyke ca. 1300 Ma. The absence of primary oil inclusions in quartz overgrowths and their presence in transgranular fractures indicates that oil migration did not occur during burial diagenesis but rather when the sandstone was well-cemented following extensive quartz overgrowth and contact metamorphism. As temperatures of entrapment in the Bessie Creek

sandstone were above about 60°C, oil migration must have occurred before significant uplift and erosion from maximum burial depth ~ 2.5 km and temperatures ~ 75°C (Powell et al., 1987) and after dolerite intrusion caused maturation in the Velkerri Formation. Entrapment in the dolerite is more poorly constrained due to possible stretching and leakage of inclusions. However, some of the oil was likely also trapped soon after magma cooling. The Bessie Creek Sandstone FIO is a mature, non-biodegraded oil that is similar to other oils, solid bitumens and source rock extracts from the Roper Superbasin (Summons et al., 1988; George et al., 1994). Based on its organic richness and proximity to the oil inclusions in both the sandstone and dolerite, the overlying Velkerri Formation is the most likely source rock. In addition, the dolerite FIO is interpreted to also contain a contribution from a high maturity condensate charge derived from a different source rock such as the Barney Creek Formation dated at 1690 Ma from the underlying McArthur Basin (Summons et al., 1988). Multiple sources are consistent with variable fluorescence colours of the oil inclusions in the dolerite dyke. Oil inclusions are repositories of palaeogeochemical information, particularly if they contain biomarkers. If the oil inclusions are present in sufficient abundance, they have the potential to provide new information on the early biosphere and ancient petroleum systems.

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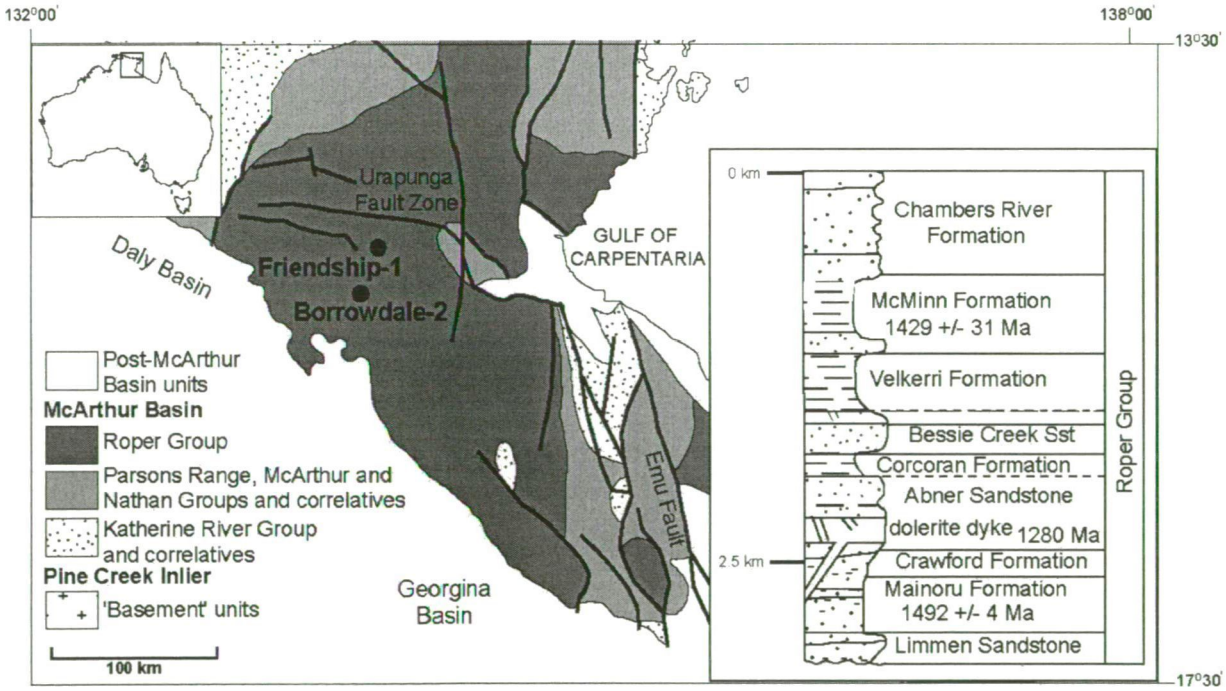

Figure 1. Location and stratigraphy of Roper Superbasin modified after Summons et al. (1988). Radiometric ages from McDougall (1965), Kralik (1982), Jackson et al. (1999), Jackson et al. (2000).