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Geochemical characterisation and predicted bulk chemical properties of petroleum generated from Jurassic and Cretaceous source rocks in the Vulcan Sub-basin, Bonaparte Basin, North West Shelf of Australia

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ABSTRACT

A geochemical investigation was carried out on 61 core and cuttings samples from selected Mesozoic source rocks in the offshore Vulcan Sub-basin of the Bonaparte Basin, Australia. Rock-Eval pyrolysis data reveal that these source rock samples contain Type II, Type II/III and Type III kerogen, with variable potential for gas and liquid hydrocarbon generation. In the Vulcan Sub-basin, samples from the marine Lower Cretaceous Echuca Shoals Formation and Upper Jurassic–Lower Cretaceous upper Vulcan Formation have fair to moderate quality organic matter. The samples from these two formations are marginally mature, but where burial is sufficient to attain higher maturity, as in the Nancar Trough to the north of the Vulcan Sub-basin, these formations have potential to be additional sources for marine oil. Samples from the marine Middle–Upper Jurassic lower Vulcan and fluvio-deltaic Lower–Middle Jurassic Plover formations contain good to very good quality organic matter. Mixed oil- and gas-prone Type II/III kerogens in the lower Vulcan and Plover formations are mature for hydrocarbon generation and can be, depending on their location and depositional environment, source rocks for oil with terrigenous and/or marine geochemical signatures. Assuming a constant geological heating rate of 3.3 °C/Ma, the onset of hydrocarbon generation (10% transformation ratio (TR)) from the Echuca Shoals and upper Vulcan formations occurs at 120 °C compared to 120–160 °C for the lower Vulcan and Plover formations. Generally, low gas/oil ratios (GORs), comparable to those measured in the natural accumulations, were reproduced at < 50% TR for both shaley coals and shales of the lower Vulcan and Plover formations. Shales of the Echuca Shoals, Vulcan and Plover formations generate paraffinic–naphthenic–aromatic (PNA) oils. Compared to the shale samples, shaley coals from the Plover Formation are kinetically more refractory and their high hydrogen indices (> 400 mg HC/g TOC) suggest the potential for high-wax PNA oil generation, in addition to wet gas.

1. Introduction

Comprehensive geochemical studies have been conducted in the Vulcan Sub-basin (Fig. 1) in order to characterise source rock potential and the properties of crude oils, condensates and gases (e.g., Scott and Hartung-Kagi, 1998; Edwards et al., 2004; Dawson et al., 2007). While gas–source rock correlations have not been established, the heterogeneous isotopic and molecular composition of the gases indicates generation from multiple Jurassic coals and marine shales over a broad range of thermal maturity (Edwards et al., 2004). In addition, an input of late dry gas to some accumulations, such as those at Skua, Montara and Padthaway in the southern Vulcan Sub-basin, and at Crux in the Heywood Graben of the Browse Basin, was recognized. Trap reactivation and alteration processes make gas-source correlation difficult, however, both the Plover and lower Vulcan formations are inferred to be the primary sources of these gases (Fig. 2; Kelman et al., 2014).

Two distinct end member groups (A and B) of oils and condensates in the Vulcan Sub-basin were delineated by Edwards et al.

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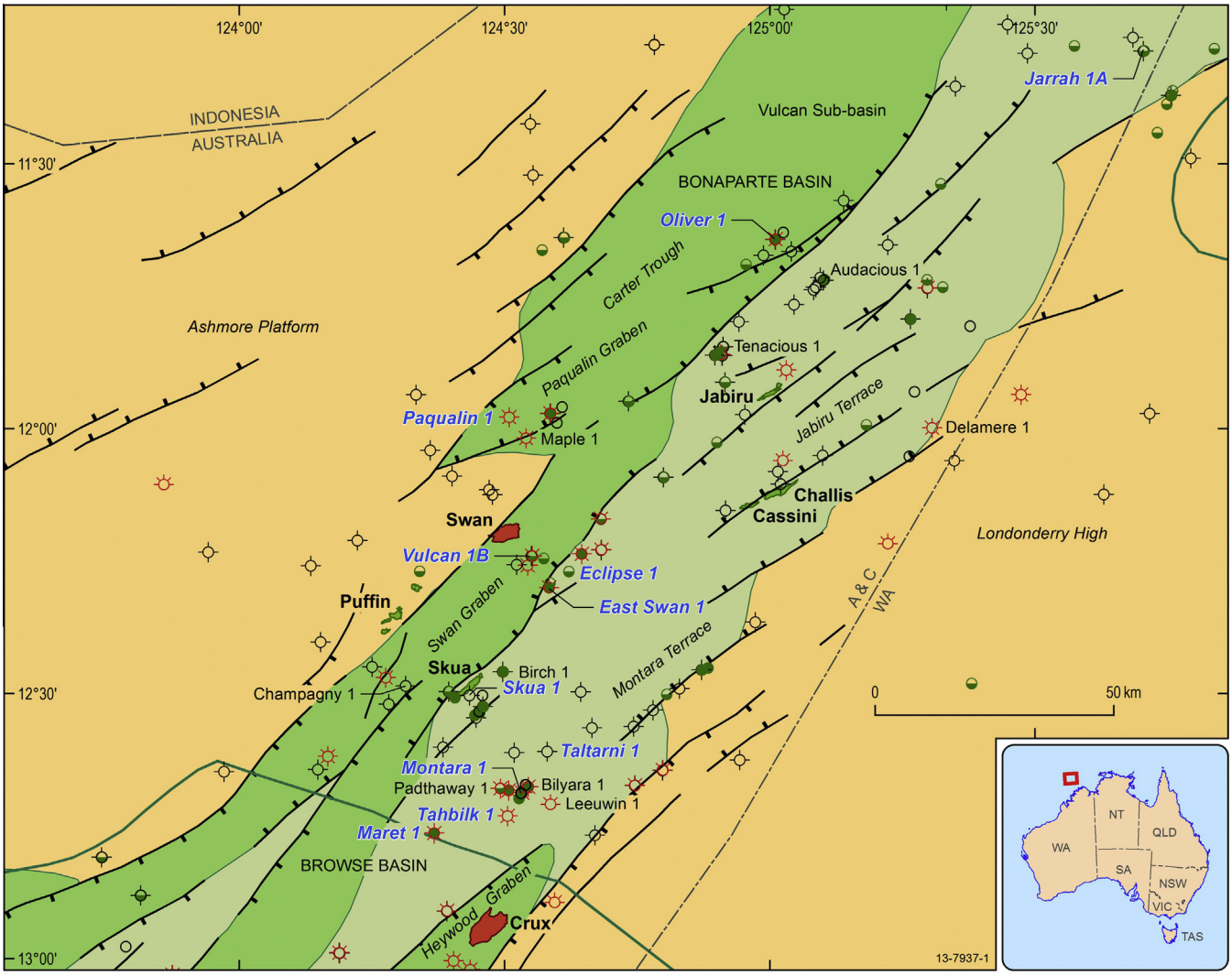

Fig. 1. Regional map showing the location and structure of the Vulcan Sub-basin within the Bonaparte Basin (NW margin, Australia) and petroleum wells (after Edwards et al., 2004). Wells, from which samples were studied are shown in blue.

(2004) based on their molecular and isotopic compositions. Group A oils and condensates (e.g., Challis, Jabiru and Skua) have marine organic precursors and originated from marine mudstones of the lower Vulcan Formation. In contrast, Group B oils and condensates (e.g., Montara, Padthaway and Maret) show more affinity to terrigenous-influenced organofacies and are thought to originate from the fluvio-deltaic mudstones and coals of the Plover Formation (Edwards et al., 2004). Oils with mixed A–B composition have been described at the Puffin and Oliver accumulations (Fig. 1) and are interpreted to originate from the Jurassic Plover Formation (and/or older source rocks) and the lower Vulcan Formation. George et al. (1997, 2004a,b) examined oil trapped in fluid inclusions (FI) in three wells across the Vulcan Sub-basin and showed that they were generated at different thermal maturity levels by either the lower Vulcan Formation (e.g., Jabiru 1A and Champagny 1 FI oils) or Plover Formation and/or older source rock (Delamere 1 FI oil). In addition to the source type and thermal maturity control on the defined oil groups, post-generation processes, such as evaporative fractionation and varying degrees of water washing, have modified the composition of the present day accumulations reservoired in the Vulcan Sub-basin (Edwards et al., 2004; Edwards and Zumberge, 2005). Both of these secondary alteration processes are associated with fault leakage and gas flushing (e.g., Lisk and Eadington, 1994; O'Brien et al., 1999; George et al., 2004b; Gartrell and Lisk, 2005). In an attempt to reconstruct the hydrocarbon charge at Jabiru 1A, Bourdet et al. (2012) mapped