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Investigations on the use of triaromatic dimethylcholesteroids as age-specific biomarkers in bitumens and oils from Arctic Norway

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ABSTRACT

Triaromatic dimethylcholesteroid (TA-DMC) and triaromatic dinosteroids (TA-dinosteroids) derive from dinoflagellates and are considered age-specific biomarkers that have some potential to distinguish between petroleum generated from Paleozoic vs Mesozoic strata. Still, some ambiguity remains concerning a gradational or abrupt Paleozoic vs Mesozoic phylogenetic change in the precursor bio-molecule for these biomarkers. Our examination of TA-DMC in a series of 112 sedimentary rock samples and oils from the Barents Sea, Svalbard, the Norwegian Sea and Novaya Zemlya ranging from the Silurian to the Cretaceous could shed light on these issues. TA-DMC together with TA-dinosteroids occur locally in Upper Permian source rocks of the Ørret Formation, while the Upper Permian Røye Formation did not reveal any occurrences. The abundance of both compound classes in Permian sediments might either suggest the presence of dinoflagellates in palaeo-niche environments during the Late Permian in the studied area, or hint towards the occurrence of related ancestors among acritarchs or non-calcifying haptophytes. TA-DMC and TA-dinosteroid were found in Lower Induan rocks from the Haltenbanken area, which implies the occurrence of TA-DMC and TA-dinosteroid producing organisms in the Early Triassic. However, the appearance of TA-DMC and TA-dinosteroids in Lower to Middle Triassic sediments from the Svalis Dome (SW Barents Sea) increases during the Anisian, while no TA-DMC have been found in Early Triassic Olenekian sequences, which is in accordance with global observations. Based on these results, it could be concluded that the 7324/8-1 Wisting Central oil discovery was generated from Olenekian intervals of the Lower Triassic Steinkobbe Formation.

1. Introduction

One of the main goals in petroleum geochemistry is to obtain a positive correlation between reservoired petroleums and organic-rich source rocks. This is the basis for the "Petroleum System" approach (Magoon and Dow, 1994). Specific biomarker distributions and molecular fingerprints support such correlations between reservoir fluids and generating source rocks (cf. Peters et al., 2005). In areas like the Barents Sea, where multiple source rocks have generated and expelled petroleum over time, a direct causal match between source rocks and reservoired petroleum is often complicated due to mixing of two or more petroleum phases (Ohm et al., 2008; Rodrigues Duran et al., 2013; Killops et al., 2014; Lerch et al., 2016a,b; Murillo et al., 2016; Abay et al., 2017a). Yet, Lerch et al. (2017a) provided geochemical evidence for the occurrence of four petroleum families in the SW Barents Sea, of which Family A was suggested to derive from Permian and Triassic source rocks; Family B comprises oils of possible Early Carboniferous age; Family C is of Jurassic age and Family D is composed of condensates that have been generated from Triassic and Jurassic source rocks. This classification was based on the use of a set of biomarker data (Lerch et al., 2017a). Still, no specific biomarkers that could link any given petroleum to a Permian source have been reported. Pedersen et al. (2017) proposed that the source rock for the 7120/1-3 Gotha oil was of Late Permian age based on the presence of gammacerane, which has so far not been documented in Triassic or Jurassic source rocks in the Barents Sea (Fig. 1). Furthermore, the absence of triaromatic 23,24-dimethylcholesteroid (TA-DMC) in the Wisting Central discovery (well 7324/8-1), the Gotha oil (well 7120/1-3) and the Senilix oil (well 7120/2-1) led Matapour and Karlsen (2017) to conclude that these petroleums were generated from a Paleozoic source rock (cf. Barbanti et al., 2011).

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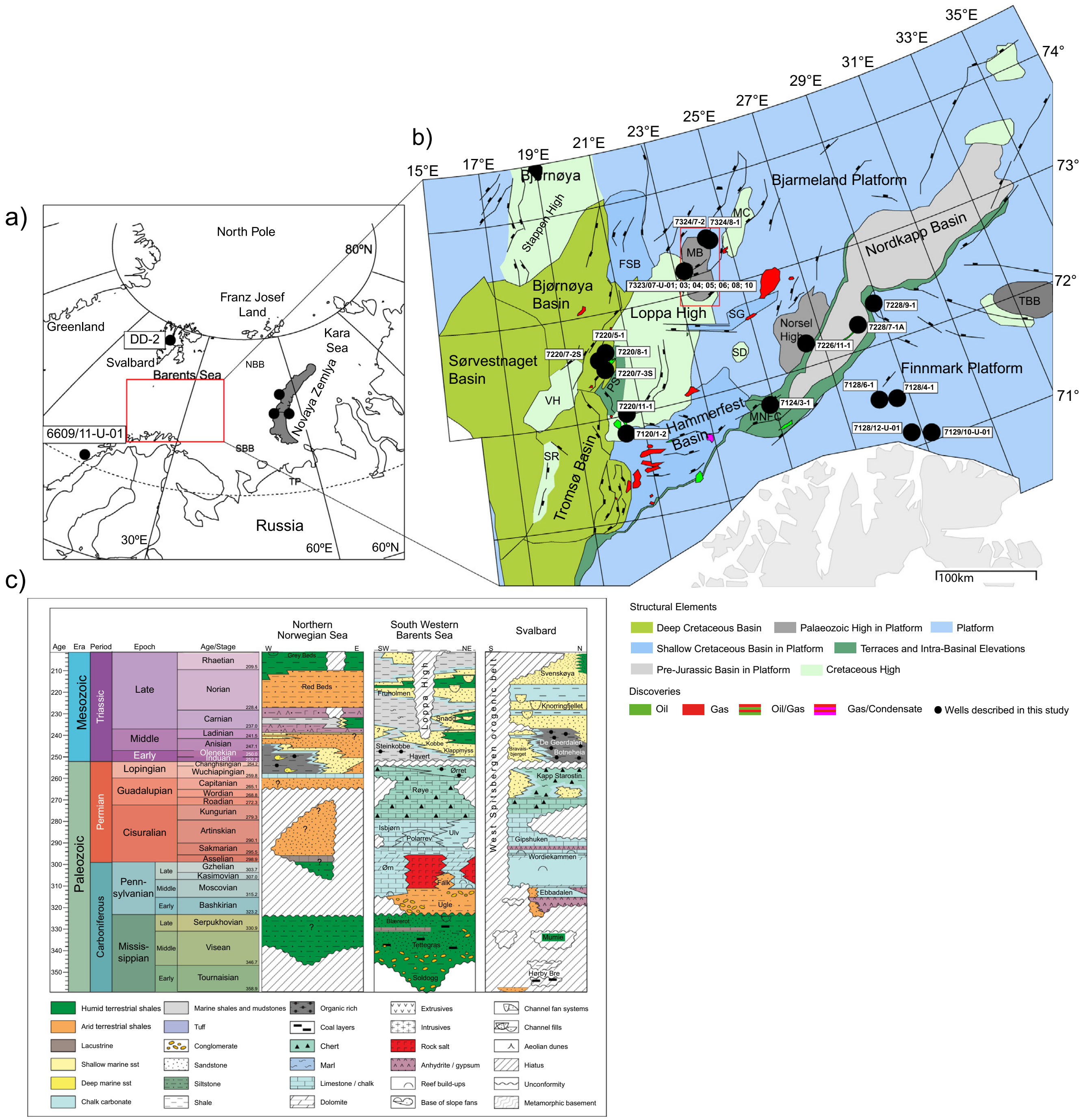

Fig. 1. (a) Arctic areas above 60° North showing the Barents Sea, Svalbard and Novaya Zemlya. Black dots indicate the samples sites (modified after van Koeverden et al., 2010b). SBB = South Barents Basin; NBB = North Barents Basin; TP = Timan Pechora region; the red polygon shows the SW Barents Sea; (b) Map showing the SW Barents Sea with well locations; and (c) Lithostratigraphic chart showing the Palaeozoic and Mesozoic for the Norwegian Sea, the SW Barents Sea and West Svalbard (modified after Norlex, 2017). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Barbanti et al. (2011) first described TA-DMC distribution patterns in a set of 102 organic-rich sedimentary rocks and 186 oil samples. TA-DMC is suggested to be derived from dinoflagellates and haptophytes (Moldowan and Jacobson, 2000; Barbanti et al., 2011). More recently, Rampen et al. (2009) reported that the precursor compounds for TA-DMC were present in over 100 diatom species dated to the Late Jurassic and younger. Appearances of TA-DMC and triaromatic dinosteroids (TA-dinosteroids) are powerful means to differentiate between Mesozoic and Paleozoic petroleums (Moldowan et al., 2001; Barbanti et al., 2011).

The application of TA-dinosteroids for age differentiation has previously been confirmed by Moldowan et al. (1996, 2001) and Empt (2004). Moldowan et al. (2001) analyzed 129 rock extracts from Proterozoic to Cretaceous age for triaromatic dinosteroids and Empt (2004) extracted 500 sedimentary rock samples from the Paleozoic in order to understand the evolution of dinoflagellates. Summons et al. (1987), Moldowan et al. (1996) and Moldowan and Talyzina (1998) reported that both dinosteranes and TA-dinosteroids are derived from sterol precursors in dinoflagellates. Thus, the concentration of TA-dinosteroids and TA-DMC should increase concordantly with the increasing appearance of dinoflagellates from the Middle Triassic and onwards. However, Moldowan and Talyzina (1998) and Moldowan and Jacobson (2000) found dinosteranes in Cambrian rocks, suggesting that