FACIES VARIATIONS WITHIN THE HEKKINGEN FORMATION: AN INTERDISCIPLINARY APPROACH

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Introduction

The Upper Jurassic Hekkingen Formation is widely spread across the Norwegian Barents Sea and is regarded as a marine source rock (NPD 2019). Marine settings are the habitat of plankton biomass deposition resulting in the formation of oil-prone, type II kerogen (Tissot and Welte, 1984). However, large variations in Hydrogen Index (HI) (figure 1A) suggest that sedimentary environments varied across the region. HI data suggest that terrestrial derived organic material, forming gas-prone, type III kerogen, in some parts of the Barents Sea could be an important contributor to the Hekkingen Formation. This research integrates detailed maceral, biomarker, isotope, and Rock-eval data from 25 wells to identify both lateral and vertical organofacies variations within the Hekkingen Formation.

Results

High gamma ray readings distinguish the lower Hekkingen shales, the Alge Member, from the upper, quartz-rich sediments, the Krill Member (figure 1B). Source rock screening shows a sudden downwards increase in Total Organic Carbon (TOC) to values generally exceeding 8%, which is generally consistent with the top of the mentioned gamma ray deflection (figure 1B). HI, however, does not enable clear discrimination between the two members. The average maceral content (%) is higher in the Alge Member, and liptinite is the dominant maceral in both units (figure 1B). A closer examination of the liptinite macerals reveals a general dominance of terrestrial-derived material (cutinite, sporinite, resinite, liptodetrinite, colonial alginite) over its marine counterpart in both members.

In the Alge Member, the relative amount of vitrinite increases towards the northern areas and towards the east of the Hammerfest basin. Terrestrial-derived liptinite generally ranges between 45-60% (figure 1C). Marine liptinite sees a gradual increase towards the west and does normally not exceed 40%. An exception is the westernmost locations where it reaches 55-70%. This is consistent with a systematic increase in the Sterane Index paired with a drop in the St29/Tt30 westwards. When analyzing samples from the Alge Member in a given well, a narrow spread (~1.5‰) in isotope fractions (AROM, SATS, ASPH) is typically observed (figure 1D), paired with a similar maceral composition (figure 1B).

Within the Krill Member, vitrinite increases towards the southernmost extension and around the Loppa High, commonly coupled with a high content of terrestrial liptinite (45-60%). Towards the westernmost area, the average content of marine liptinite increases up to 75%, accompanied by increasing Sterane Index. Vertical variations in the maceral composition are ubiquitous within the Krill Member (figure 1B), which are reflected in a significantly higher spread (~4.0‰) in isotope values (figure 1D).

Discussion

The Alge Member's increase in marine biomass towards the west suggests a westwards transition from terrestrial-dominated influx to relatively more marine-dominated conditions.

Significant influx of terrestrial biomass continued well into the deposition of the overlying Krill Member, where it diluted with higher content of quartz (figure 1B) in relatively higher energy environments. Subaerial exposure of the Loppa High acted as a new source of vitrinite to the Krill Member.

Although lateral variations exist within both members, the Alge Member is vertically more homogenous than the Krill Member (figure 1B). Such heterogeneity in the former unit could be a response to tectonically driven and/or episodic fluctuations in sea level triggering changes in the organic matter input. Ongoing work on isotope fractions has also proven useful in recognizing this heterogeneity. They seem to allow a correlation between terrestrial-derived macerals and lighter isotopes, and similarly between marine macerals and heavier isotopes.

Terrestrial-derived material (terrestrial liptinite + vitrinite), accounting for an average 65%, are the main biomass contributor to the Hekkingen Formation. Vitrinite and liptinite of terrestrial origin help to discriminate depositional environments near the coast. Samples containing high percentages of terrestrial-derived liptinite, however, appear to be as oil prone and prolific as marine (figure 1C).

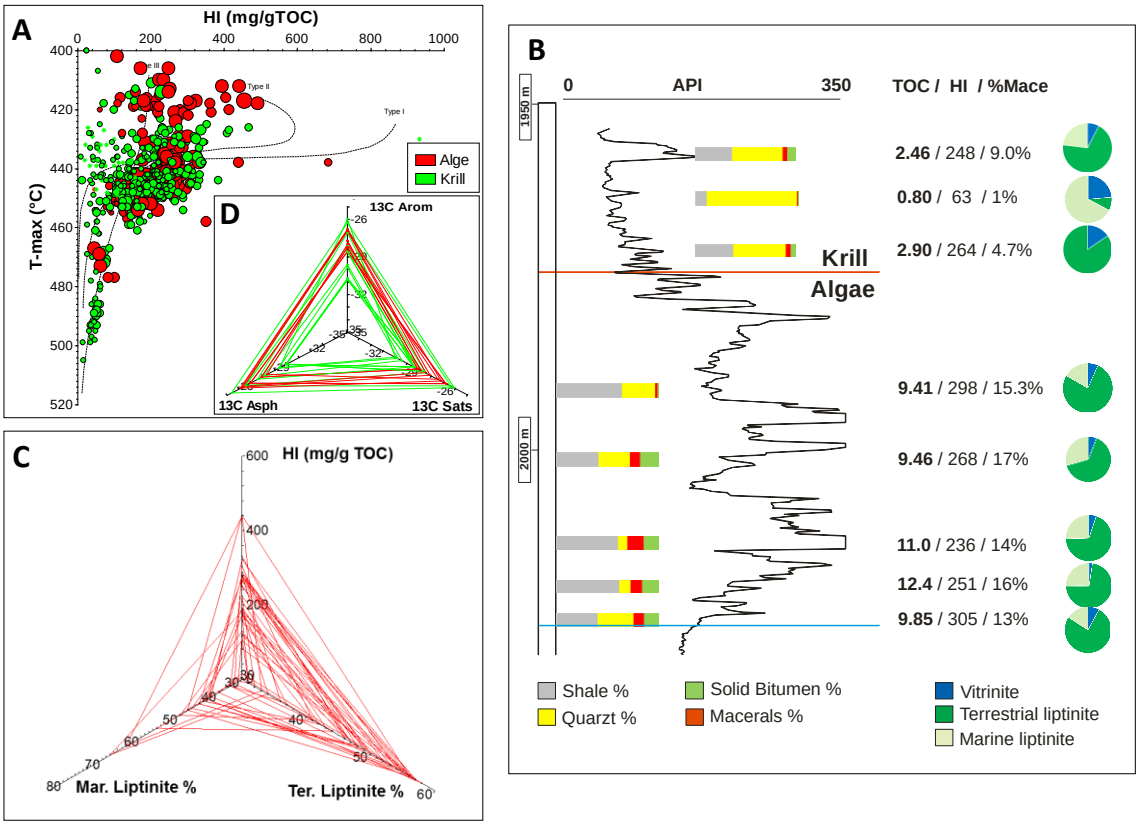

Figure 1. A. *Tmax versus Hydrogen Index diagram;* ***B.*** *Gamma ray log of the Hekkingen Formation showing differences in the two members;* ***C.*** *Star diagram showing Marine Liptinite, Terrestrial Liptinite, and Hydrogen Index in the Alge member* ***D****. Star diagram showing AROM, SATS, and ASPH isotope fractions.*

References

NPD (2017) Norwegian Petroleum Directorate Factpages.

B.P Tissot and D. H. Welte, 1984, Petroleum formation and occurrence. 2d ed: New-York, Springer Verlag, 699 p.