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The Light Hydrocarbon Paradox of the Barents Sea- Light Hydrocarbon Correlation- & Transformation-Parameters in Barents Sea Oils & Condensates



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Introduction

Cenozoic uplift and erosion are thought to have essential influence on the redistribution, composition and alteration of generated hydrocarbons in the Barents Sea. As the Barents Sea represents an overfilled multiple source rock basin (Ohm et al., 2008), geochemical investigation of oil and gas/condensate samples will improve our understanding of the petroleum systems.

This study focusses on the light hydrocarbon (LHC) fraction as these compounds make up significant volumes of oils/condensates, are the most mobile and recently migrated, but also the easiest lost compounds of petroleum. LHC thus provide a recent and dynamic insight into migration and alteration processes.

Compared to commonly applied biomarkers from the $nC_{15}+$ range, LHC still hold valuable information of alteration even in high mature samples. Post emplacement alteration such as evaporitic fractionation, biodegradation and water-washing/long-distance migration were found to occur in the LHC of the samples.

Besides geochemical practice, fundamental geological aspects as proposed by Gussow (1954) and Silverman (1965) were adapted to explain the distribution and composition of the samples. Whereas brittle/thin/silty cap-rocks hold back oil and leak gasoline range compounds, tight cap-rocks hold back both phases (Sales, 1997; Karlsen and Skeie, 2006).

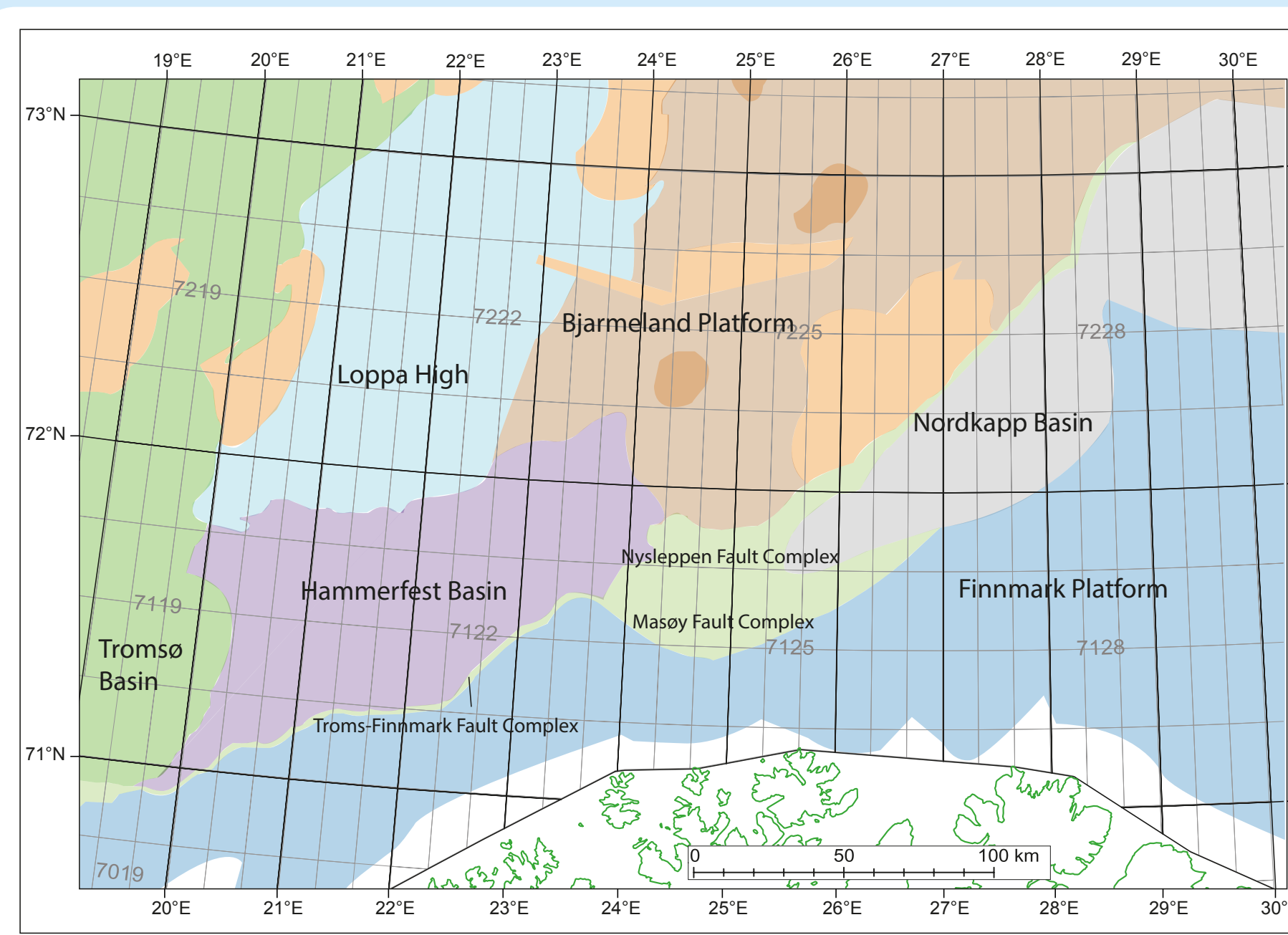


Figure 1: Map showing the main structural elements in the study area. The samples derived from wells in the Tromsø Basin, the Hammerfest Basin, the Loppa High, the Måsøy/Nysleppen Fault Complex, the Bjarmeland Platform and the Nordkapp Basin were collected from traps varying from Late Carboniferous-Early Perm to Early Cretaceous age.

Methods

Forty-six oil and condensate samples from the Loppa High, the Hammerfest Basin, the Måsøy/Nysleppen Fault Complex, the Bjarmeland Platform, the Finnmark Platform and the Nordkapp Basin were geochemically investigated. LHC parameters as recommended by Thompson (1987) and Halpern (1995) (Fig.2) were calculated based on measured peak heights derived from gas chromatography - flame ionization detection (GC-FID).

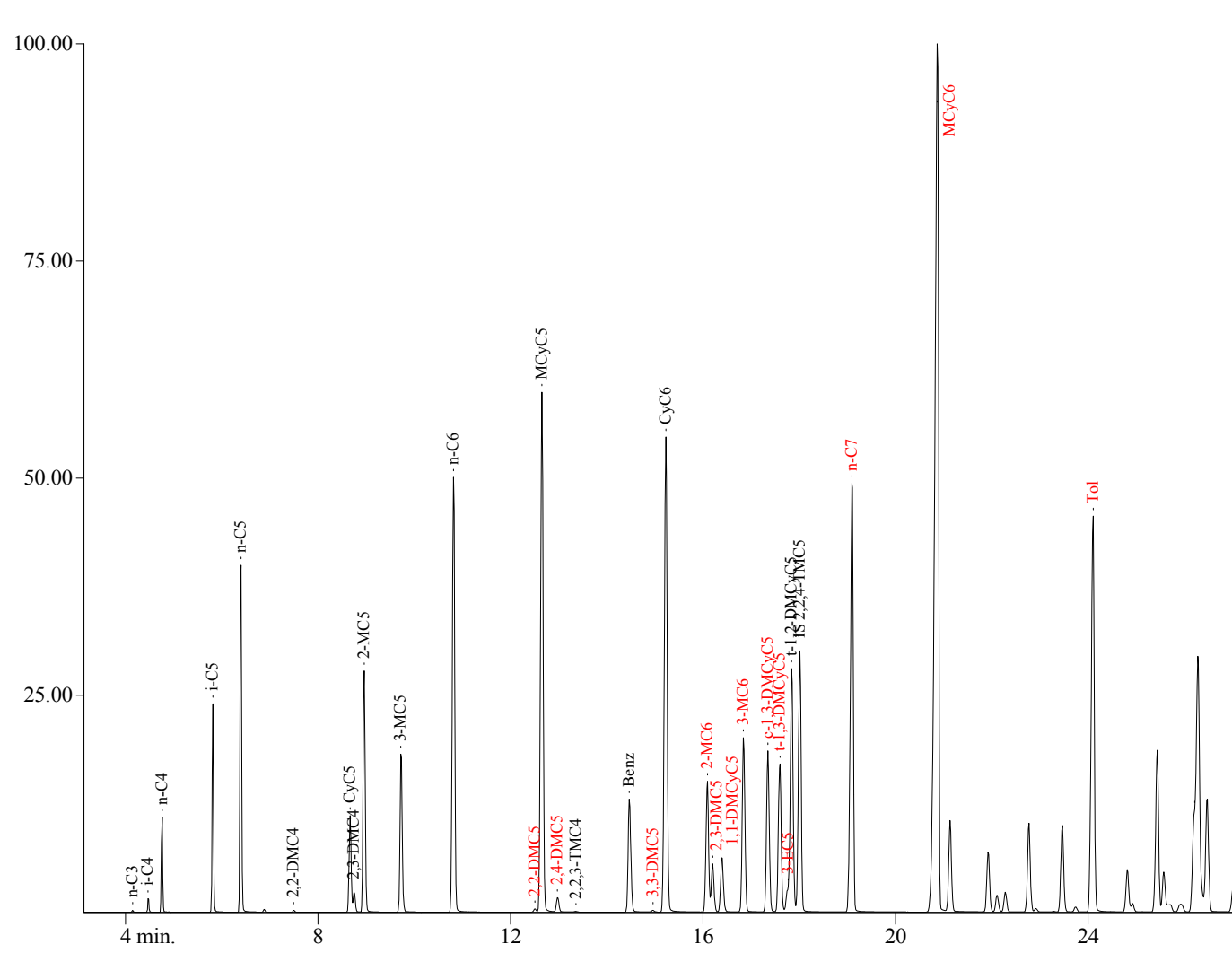


Figure 2: Representative chromatogram displaying the applied LHC in red.

Halpern (1995)	
Ratio	Compounds*
Tr1	Toluene/1,1-DMC ₅
Tr2	n-C ₇ /1,1-DMC ₅
Tr3	3-MC ₆ /1,1-DMC ₅
Tr4	2-MC ₆ /1,1-DMC ₅
Tr5	P2/1,1-DMC ₅
Tr6	cis-1,3-DMC ₅ C ₅ /1,1-DMC ₅
Tr7	trans-1,3-DMC ₅ C ₅ /1,1-DMC ₅
Tr8	P2/P3
Thompson (1987)	
Ratio	Compounds
B	Toluene/n-Heptane
F	n-Heptane/Methylcyclohexane

Results & Discussion - I

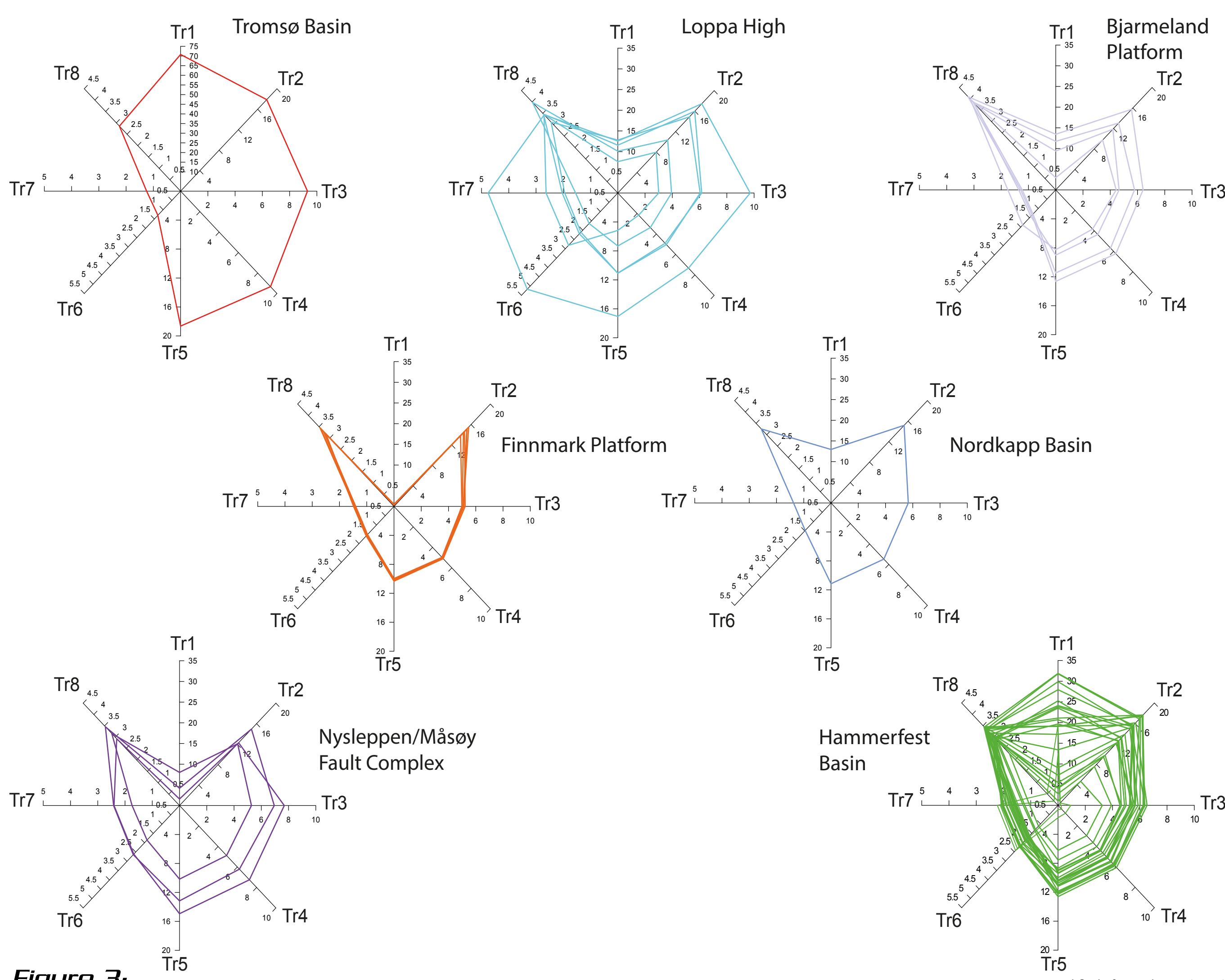


Figure 3: Oil Transformation Star Diagrams representing different alteration mechanisms in the LHC fraction. Low Tr1 values characterize water-washing and/or long-distance migration of the LHC due to the loss of the water soluble compound toluene, whereas high Tr1 values illustrate locally arrived LHC. Decreasing values for the Tr2-Tr5 and Tr7-Tr8 parameters indicate biodegradation. The Tromsø Basin sample is the most unaltered sample in the database (note the different Tr1 scale). Locally derived and long-distance migrated HC are found in the Hammerfest Basin. All other samples represent migrated LHC fractions based on their reduced toluene content. The very low Tr1 values for the Finnmark Platform might be a source rock effect. High Tr2-Tr8 values for one Loppa High sample indicate a fresh gas-charge.

Results & Discussion - II

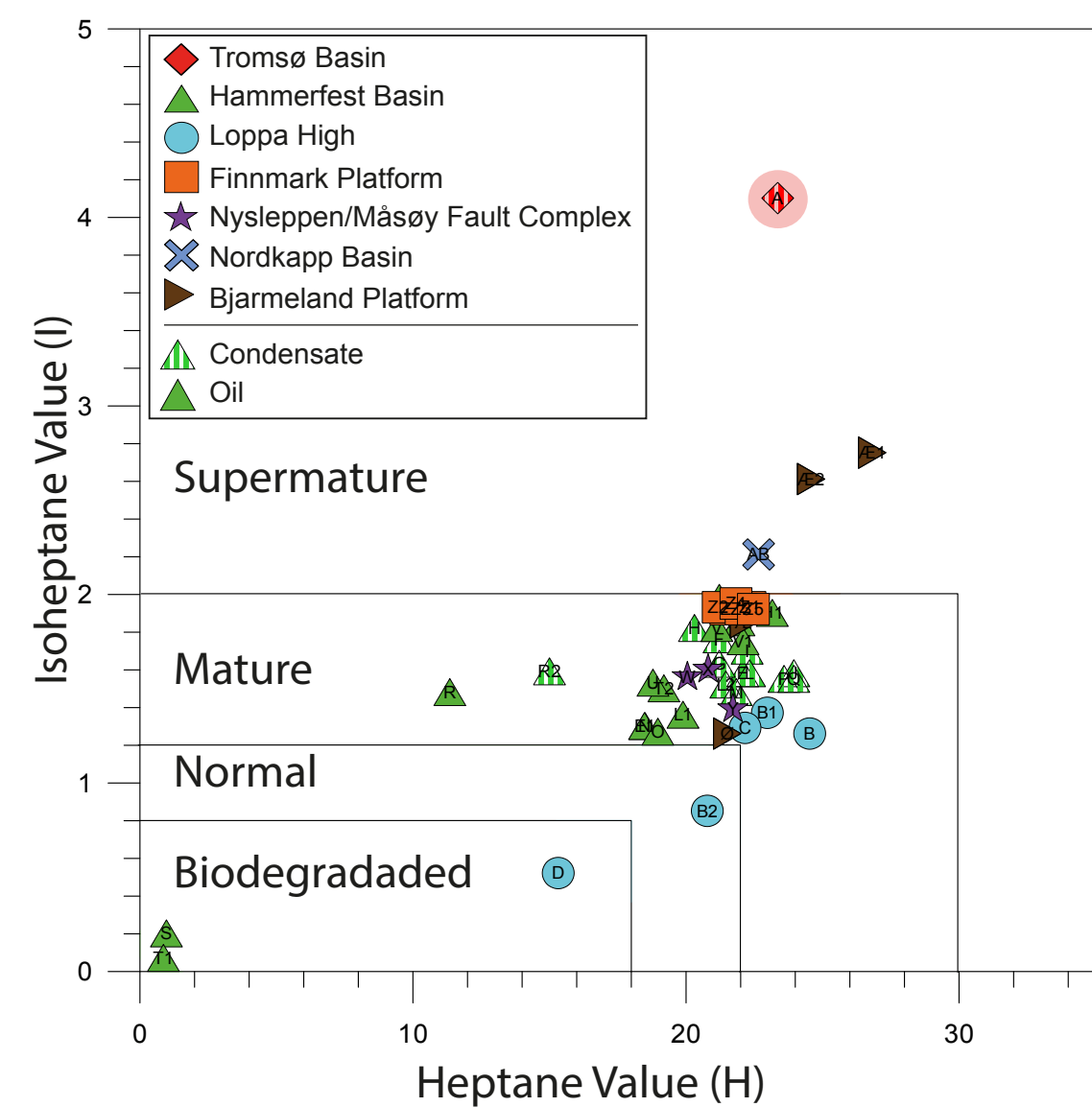


Figure 4: Diagram showing different maturity levels and biodegradation of the samples. Two samples from the Hammerfest Basin (Goliat) are biodegraded. Lowest maturity is found in the samples from the Loppa High. Samples from the Finnmark Platform, the Nordkapp Basin, the Bjarmeland Platform and the Tromsø Basin show highest maturity.

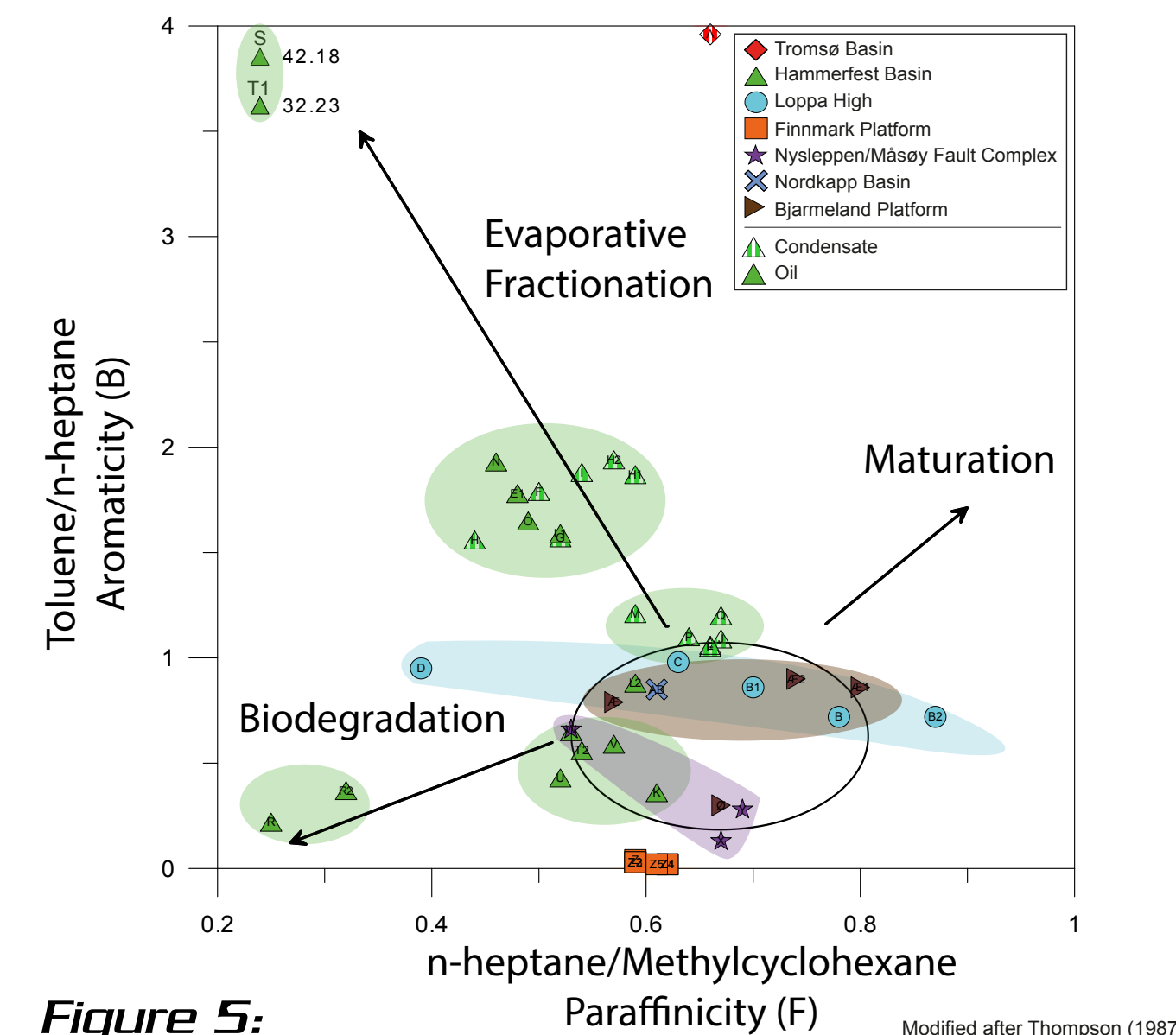


Figure 5: Cross-plot illustrating several condensate and oil samples from the Hammerfest Basin as fractionated. High aromaticity values for condensates reveal several gas-stripping events. Fractionated oils were found under gas-caps indicating the traps were able to hold back both phases and that it is big enough not to spill all oil. Samples indicating biodegradation correlate well with Fig. 3 and Fig. 4.

Results & Discussion - III

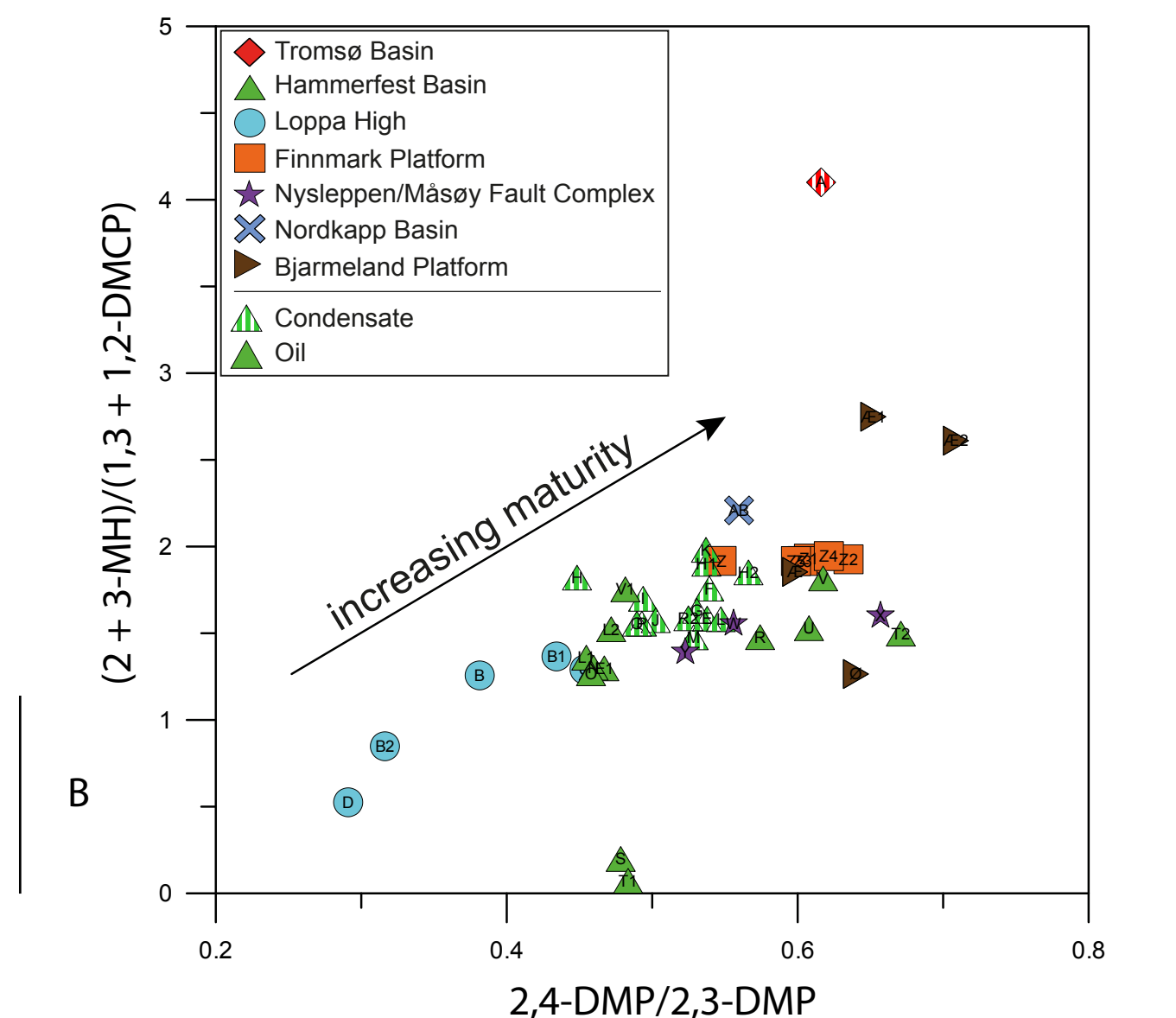
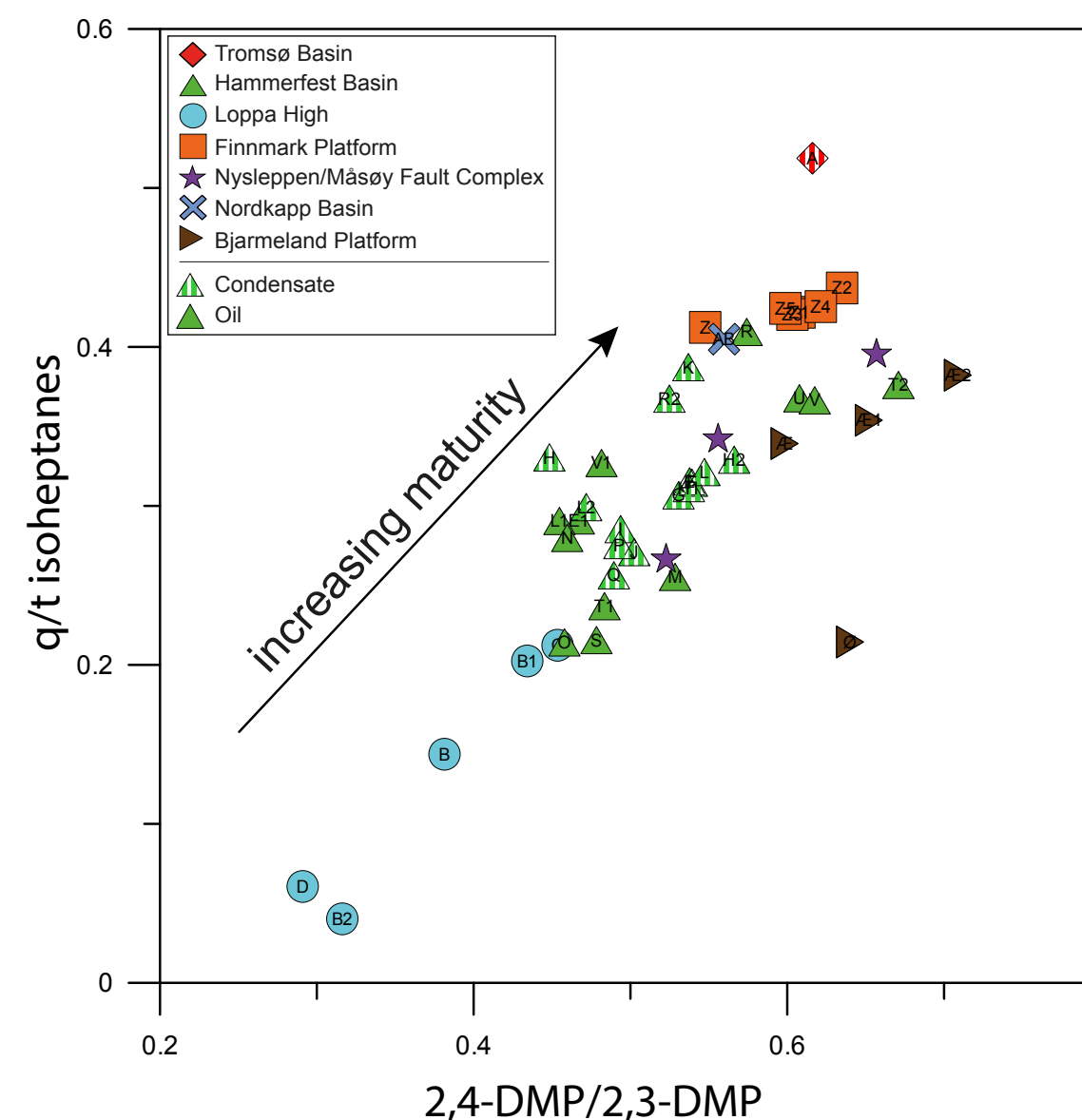


Figure 6: Two crossplots (A) and (B) modified after Chung et al., (2004) illustrating different maturities in the study area. The Loppa High samples show the lowest maturity. Samples from the Hammerfest Basin and the Måsøy/Nysleppen Fault Complex plot with medium maturities, whereas samples from the Nordkapp Basin, the Bjarmeland Platform, the Finnmark Platform and the Tromsø Basin are characterized by highest maturities. These results correlate very well with observations made in Fig. 4.

Results & Discussion - IV

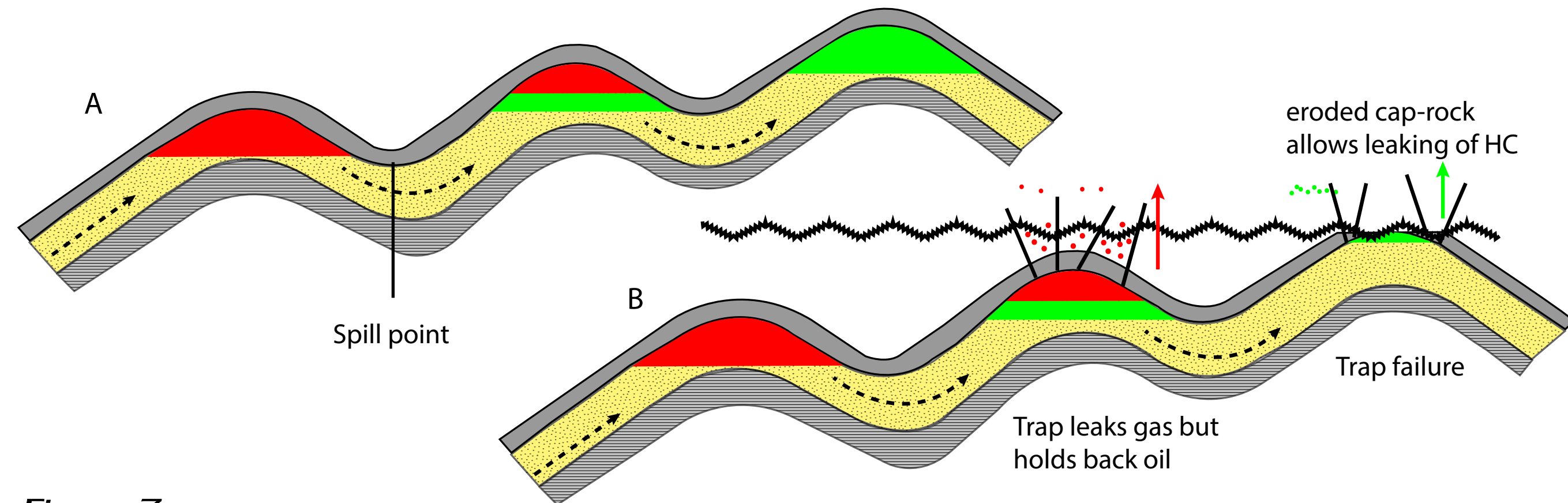


Figure 7: Two models illustrating the difference between a tight and a brittle cap-rock. A) Tight cap-rock model - 1: Gas expansion due to uplift. The oil remigrates up into the 2nd trap. 2: The oil separates into a gaseous and liquid phase whereas the gas expands again and pushes the oil upward into the 3rd trap. The cap-rock has the ability to hold back both oil and gas. B) Brittle cap-rock model - 1: Gas expansion due to uplift and the oil phase migrates up into the 2nd trap. 2: Uplift induced brittle cap-rock leaks gas but holds back oil. 3: Syn-uplift remigrated oil leaks out of the trap due to uplift induced erosion of the cap-rock.

Conclusions

- 1) High toluene and benzene contents reveal oil and condensate samples from the Tromsø Basin and Hammerfest Basin as **locally derived**, whereas **long-distance migration** has affected the LHC in most other oil samples. Low toluene and benzene content in the biodegraded samples might be a result of combination of water-washing and long-distance migration.
- 2) **Evaporative fractionation** occurs only in the Hammerfest Basin. Most of the fractionated samples are condensates with high aromaticity values which points towards repeated gas-stripping episodes. Fractionated oil samples lie under gas-caps with tight cap-rocks. Some oils show a waxy *n*-alkane signature that points towards palaeo oil generation. Traps that are not filled to spill-point might explain the occurrence of these waxy oils beneath the condensates.
- 3) LHC **biodegradation** is limited to oils on the proximal basin margins in the Hammerfest Basin which might be related to the occurrence of fragile cap-rocks and traps allowing water to intrude
- 4) **Highest maturity** is recorded for oil samples on the Finnmark Platform, the Bjarmeland Platform and the Tromsø Basin condensate while oils from the Loppa High show **low maturities**.

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