



Novel Results on Migrated Oil in several Svalbard out-crop samples: What does this tell us about the Petroleum Systems responsible for the Migrated Oils in these samples?

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Introduction

While the shaly source rocks of Botneheia have been investigated in detail at Svalbard in terms of organic geochemistry since the early 80ties, it is, with a very few exceptions, only relatively recently that focus has been directed towards manifestations of migrated hydrocarbons in other lithologies.

Recently, we have had the possibility to evaluate bitumen or migrated oil from several locations at Svalbard, and these data, representing typically sandstones, siltstones and carbonaceous mudstones struck us by containing often full spectrum of normal alkanes from about C₁₅ and onwards and suggest that oil has been migrated from thermally mature source rocks. At Svalbard mature source rocks are known from Triassic (e.g. Botneheia Fm.), Jurassic (e.g. Agardhfjellet Fm.) and also from the Lower Cretaceous Carolinefjellet Fm.. The Kolje Fm. has also recently been suggested as having source rock qualities in western parts of the Barents Shelf.

Rock Eval data from well DH4 and DH5R show that the Upper Jurassic Agardhfjellet Fm. is thermally mature (PI, 0.25-0.40 and Tmax 452-467 °C) and it is more waxy compared to the Hekkingen Fm..

For this study several outcrop samples were obtained from various localities in Svalbard (Fig. 5). The samples were cleaned with water and dried at room temperature before being crushed into powder in a steel mill. To extract the bitumen from the crushed samples, a conventional Soxtec extraction unit was used. A mixture of dichloromethane and methanol (93:7 vol%) was used as extraction solvent. The bulk extracts were then analysed by Gas Chromatography-Flame Ionization Detector (GC-FID) and Gas Chromatography-Mass spectrometry (GC-MS) to obtain n-alkanes and biomarkers.

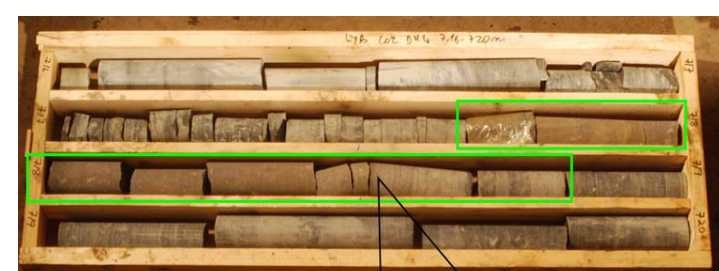


Photo 1: Oil stained Triassic sandstones in well DH4, oil stains are indicated in the ~717.5-718.8 m interval.

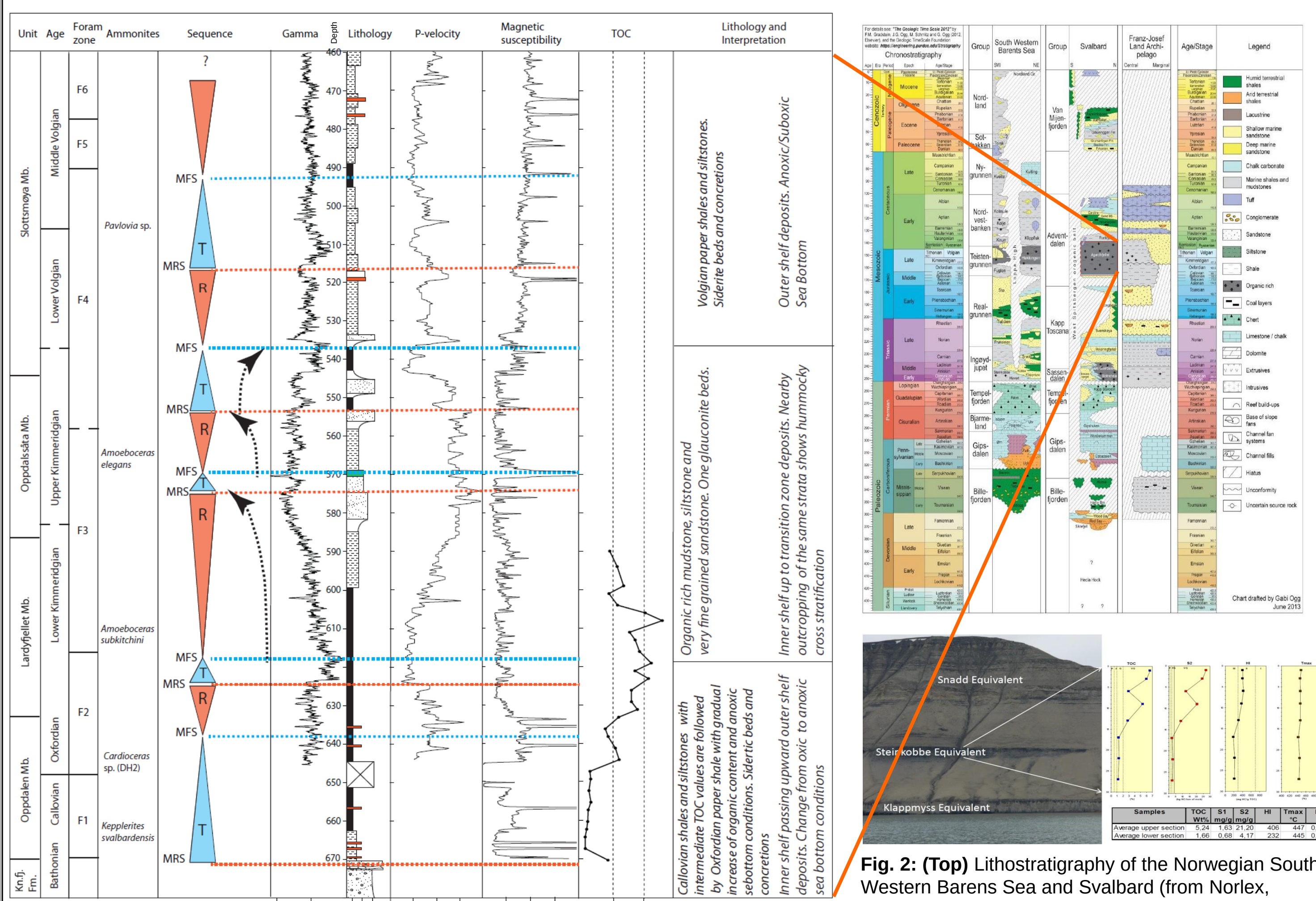


Fig. 1: Diamond core drilled and logged section of the Agardhfjellet Formation i.e. the Fuglen and Hekkingen formations equivalent in the Barents Sea. Probably one of the few examples of a fully cored Upper Jurassic source rock units. Clastic wedges split the Agardhfjellet Formation into a lower (Lardylfjellet Member) and an upper (Slottsmaya Member) organic rich units. Wireline logs and core description have revealed both coarsening and fining upward log motifs. The two CU sequences are interpreted as a distal response to a southwards Kimmeridgian prograding coastline, two clinotherms. Note the high sudden influx of higher TOC in the Oxfordian transgressive phase and very high TOC values (13%) in the early phase of the first Kimmeridgian prograding wedge.

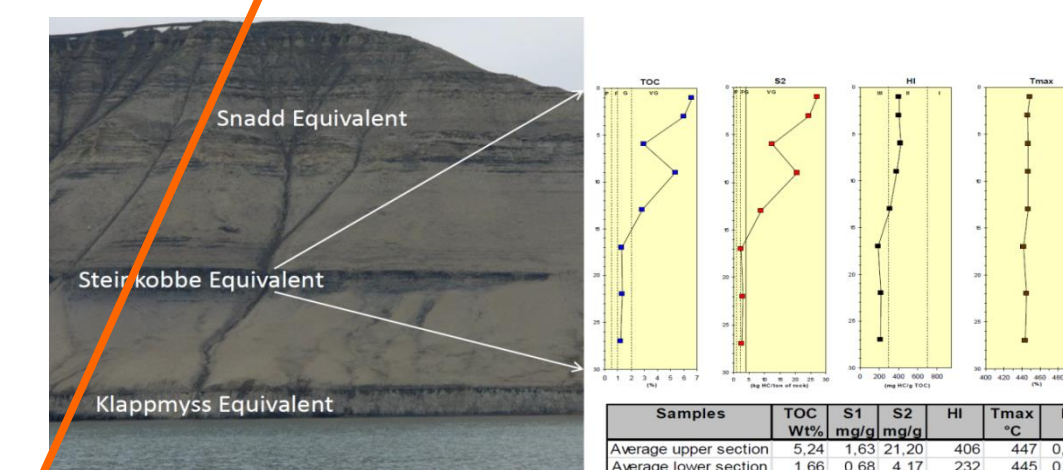


Fig. 2: (Top) Lithostratigraphy of the Norwegian South Western Barents Sea and Svalbard (from Norlax, accessed in May 2014) and (Bottom) Triassic source rocks exposed at Svalbard. In the Barents Sea the Snadd, Steinkobbe/Kobbe and Klappmyss and Havert Fms. are proved Triassic source rocks. Their time equivalent Fms. at Svalbard are the De Geerdalen, Botneheia and Vikinghøgda Fms. The Middle Triassic Botneheia/Kobbe/Steinkobbe Fm. comprises organic rich sediment and is the best oil prone Triassic source rock in the region. Values of Rock-Eval data from this Fm. are indicated in the lower right chart.

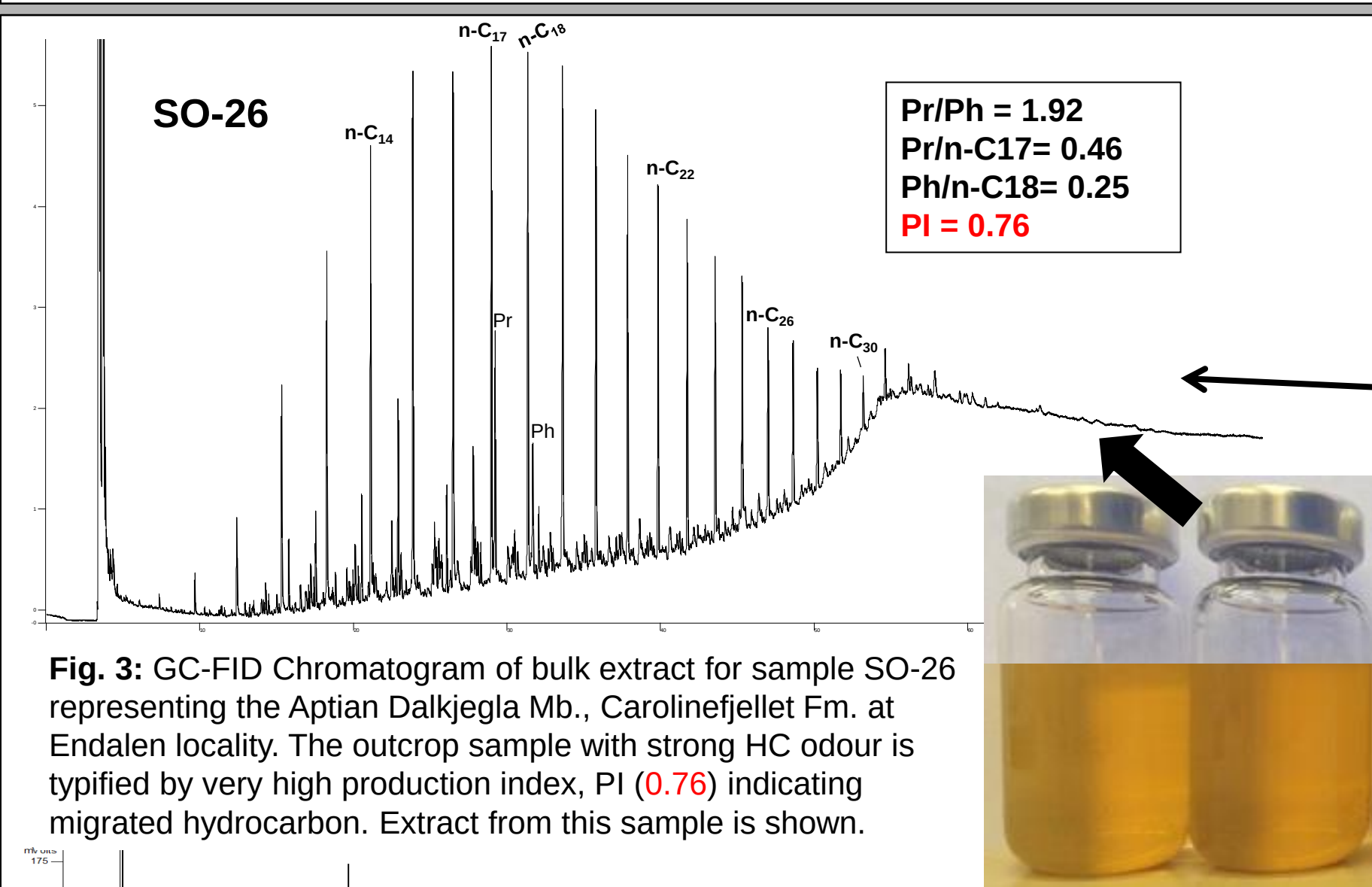


Fig. 3: GC-FID Chromatogram of bulk extract for sample SO-26 representing the Aptian Dalkjegla Mb., Carolinefjellet Fm. at Endalen locality. The outcrop sample with strong HC odour is typified by very high production index, PI (0.76) indicating migrated hydrocarbon. Extract from this sample is shown.

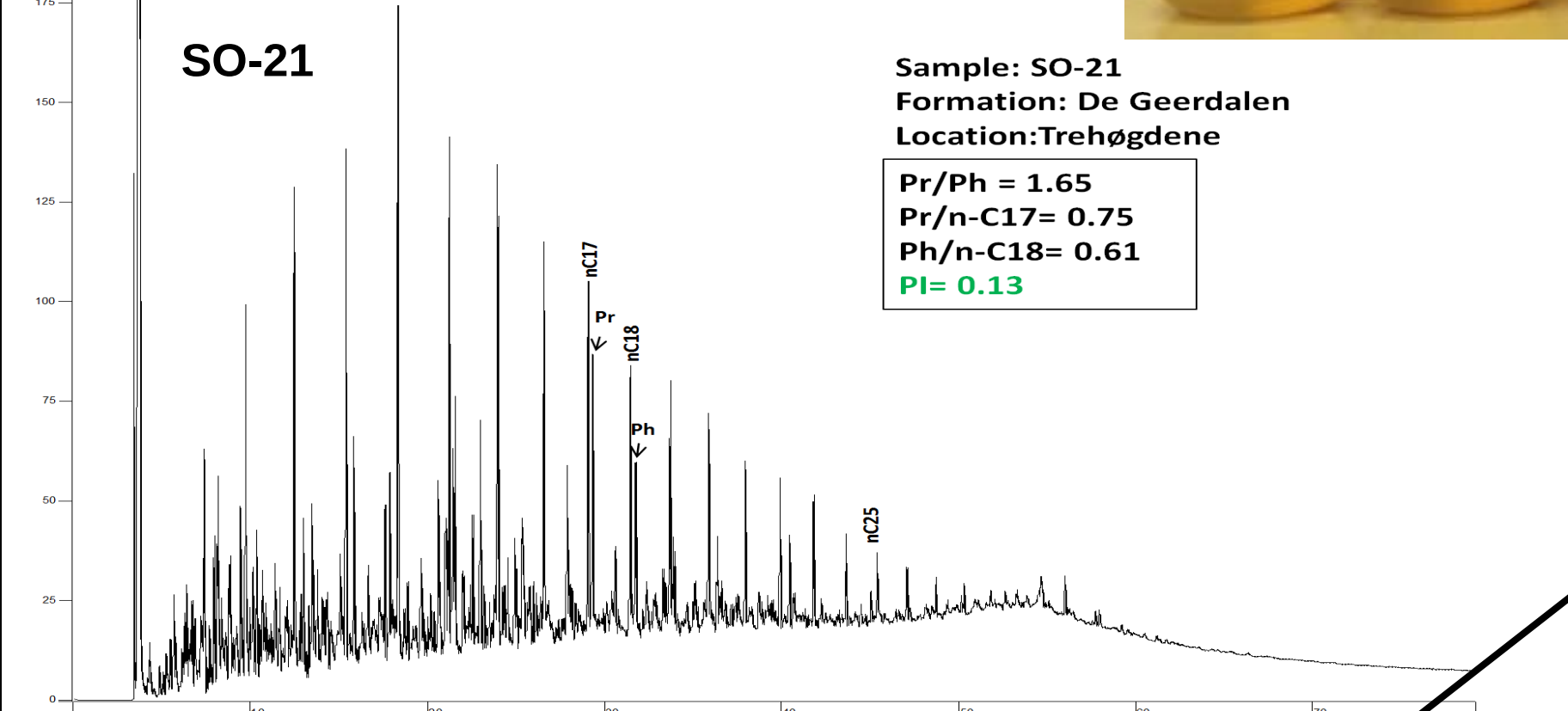


Fig. 4: GC-FID Chromatogram of bulk extract for sample SO-21 from the Upper Triassic De Geerdalen Fm. at Trehøgden locality representing in-situ source rock extract with n-alkanes out to about C₃₀. The maturity of this sample is indicated to be about 0.9-1%Rc and production index (PI) is 0.13 and its organofacies is marine mixed Type II/III.

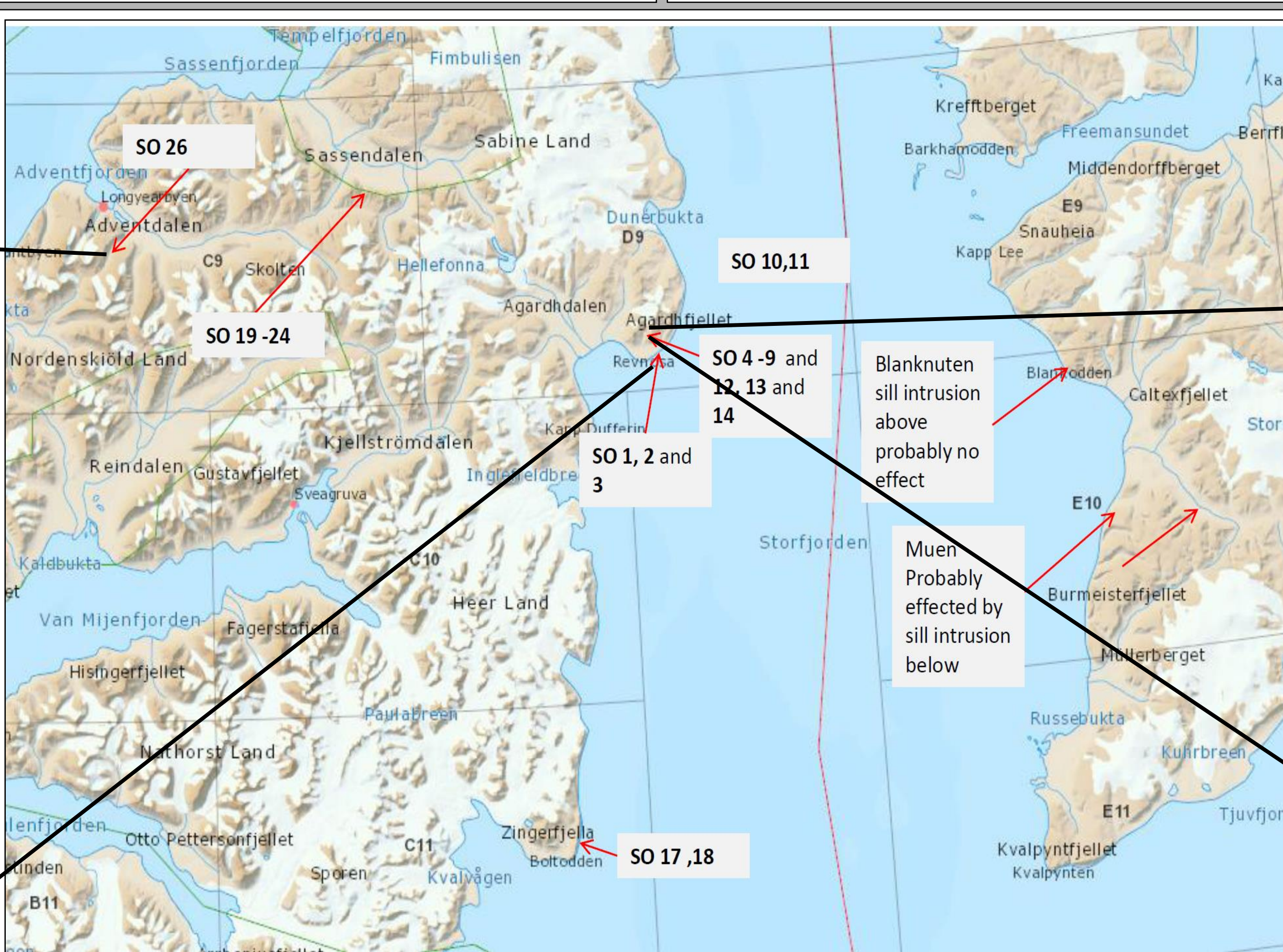


Fig. 5: Map of Svalbard showing different localities. Sample names are given as for example SO 1, SO 2...; red arrows indicate the location of the samples.

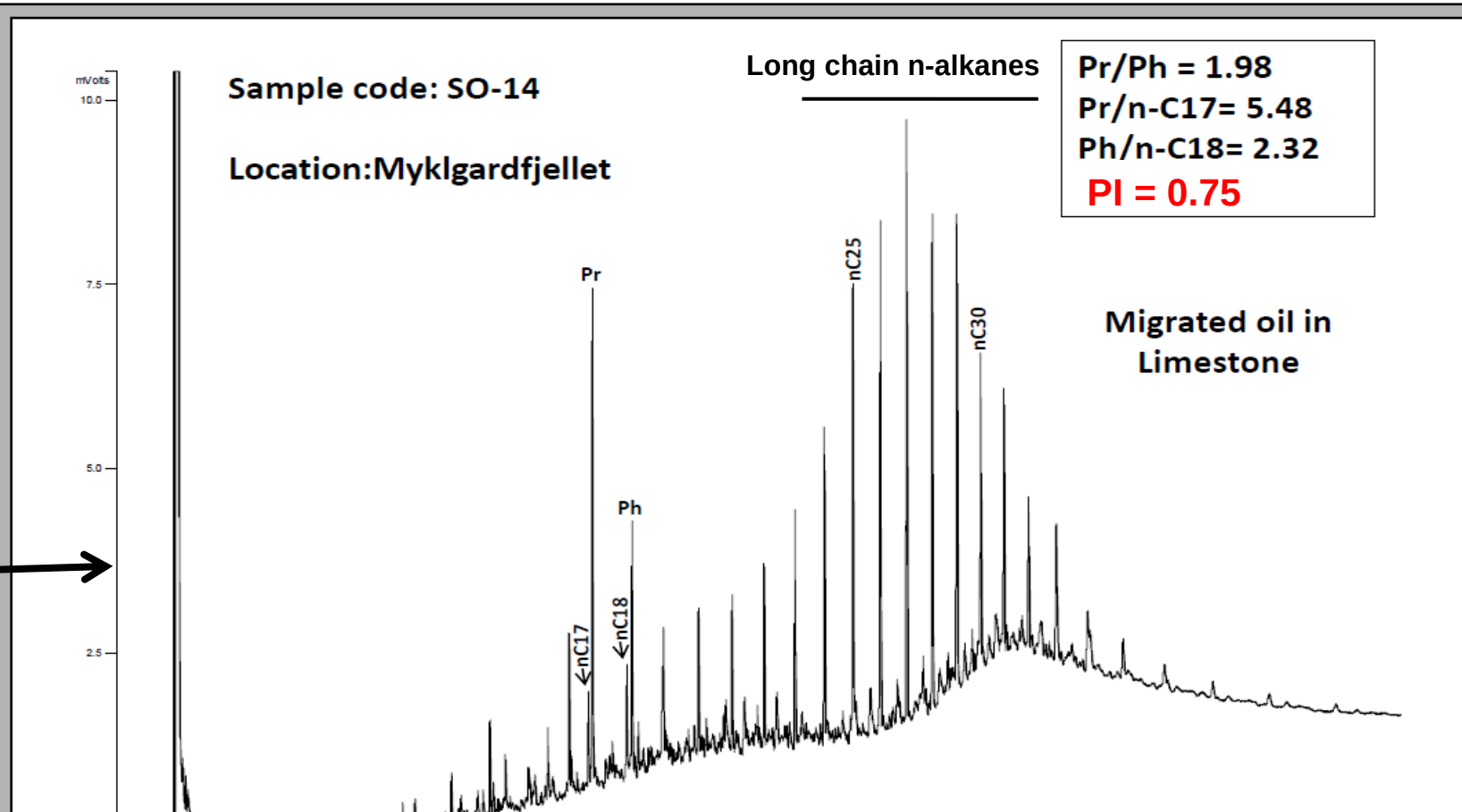


Fig. 6: GC-FID chromatogram of bulk extract for sample SO-14 representing migrated petroleum. The sample, limestone & taken from the Agardhfjellet Fm., show an abundance of long chain (>C₂₅) n-alkanes indicating oil sourced from terrigenous sediments.

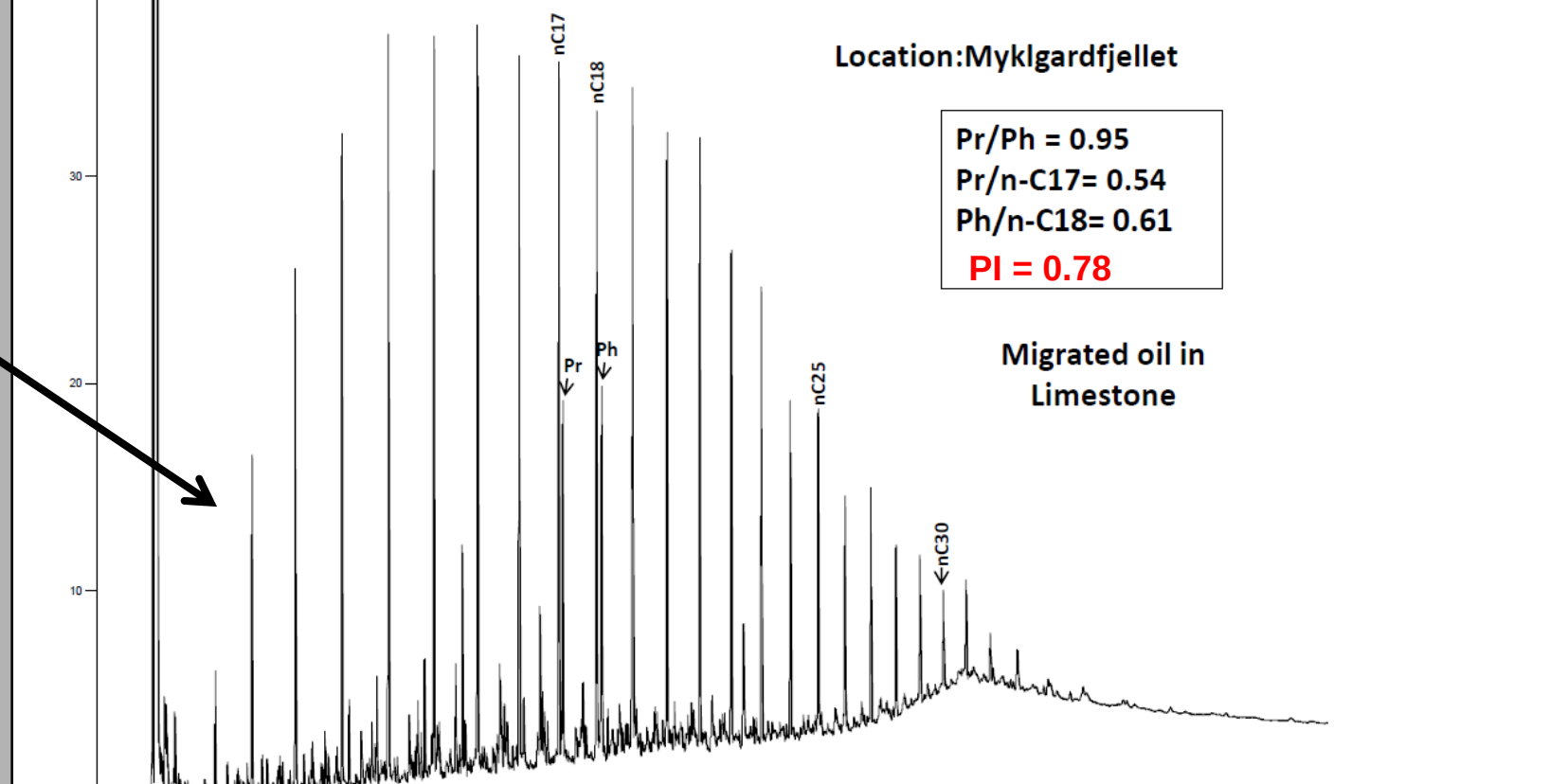


Fig. 7: GC-FID chromatogram of bulk extract for sample SO-13. The sample is limestone and this chromatogram represents mature oil signature with n-alkanes up to about C₃₅.

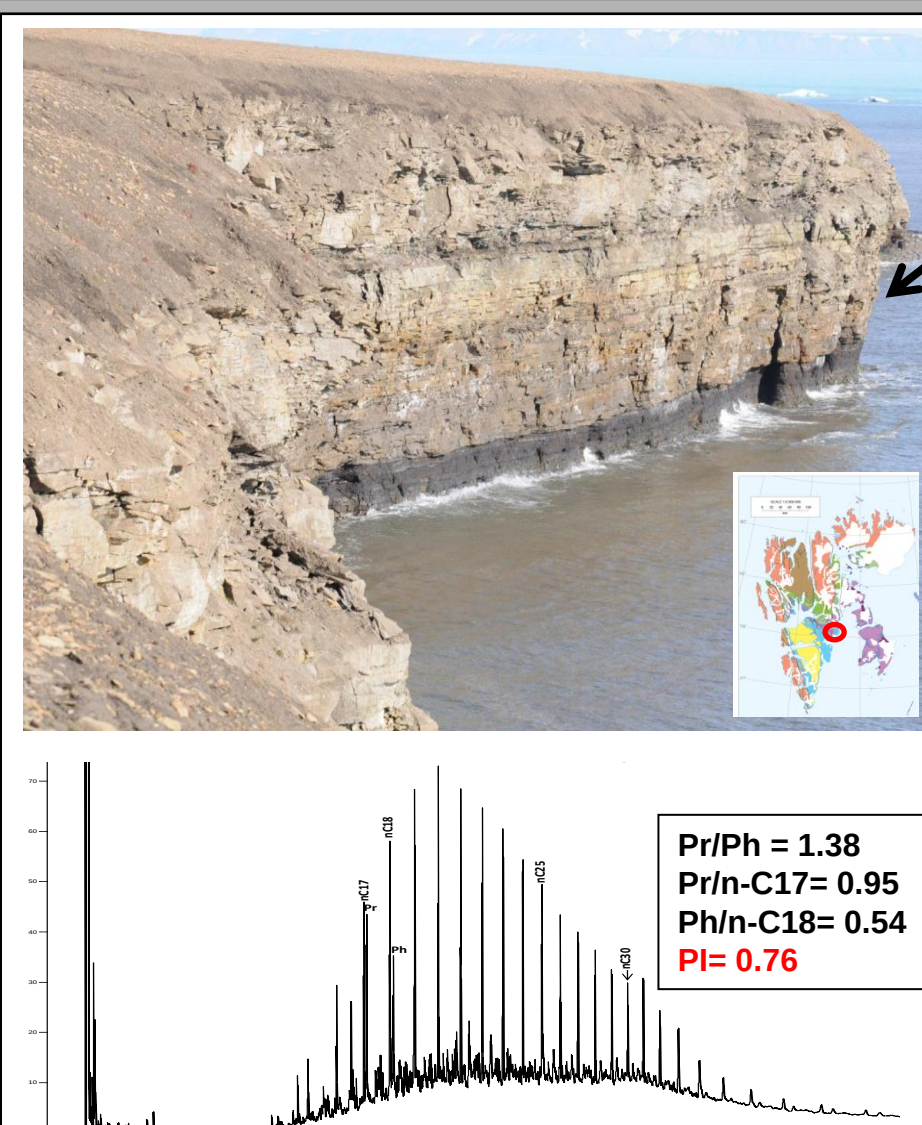


Fig. 8a: Outcropping hydrocarbon-stained Wilhelmøya Subgroup (onshore equivalent to the Realgrunnen Subgroup) in East Spitsbergen. Cliff height is 30m.

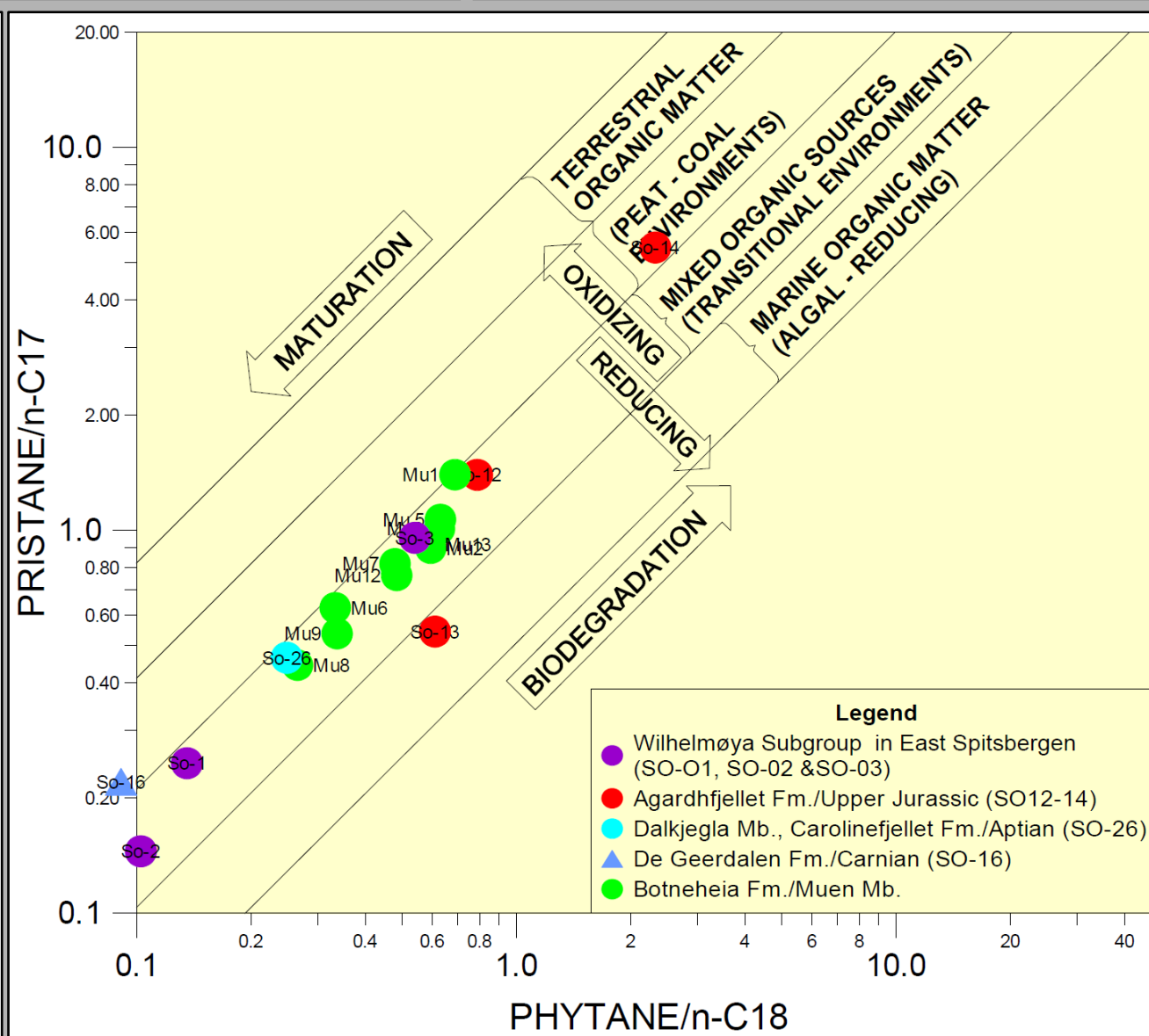


Fig. 9: Logarithmic display of the ratios of pristane to the n-C₁₇ alkane (Pr/n-C₁₇) and phytane to the n-C₁₈ alkane (Ph/n-C₁₈) (Modified from Shanmugam, 1985). Most samples are plotted in the Transitional environment which suggest a mixed organic source. Sample SO-14 is plotted differently and represent an organic matter input from oxic environment.

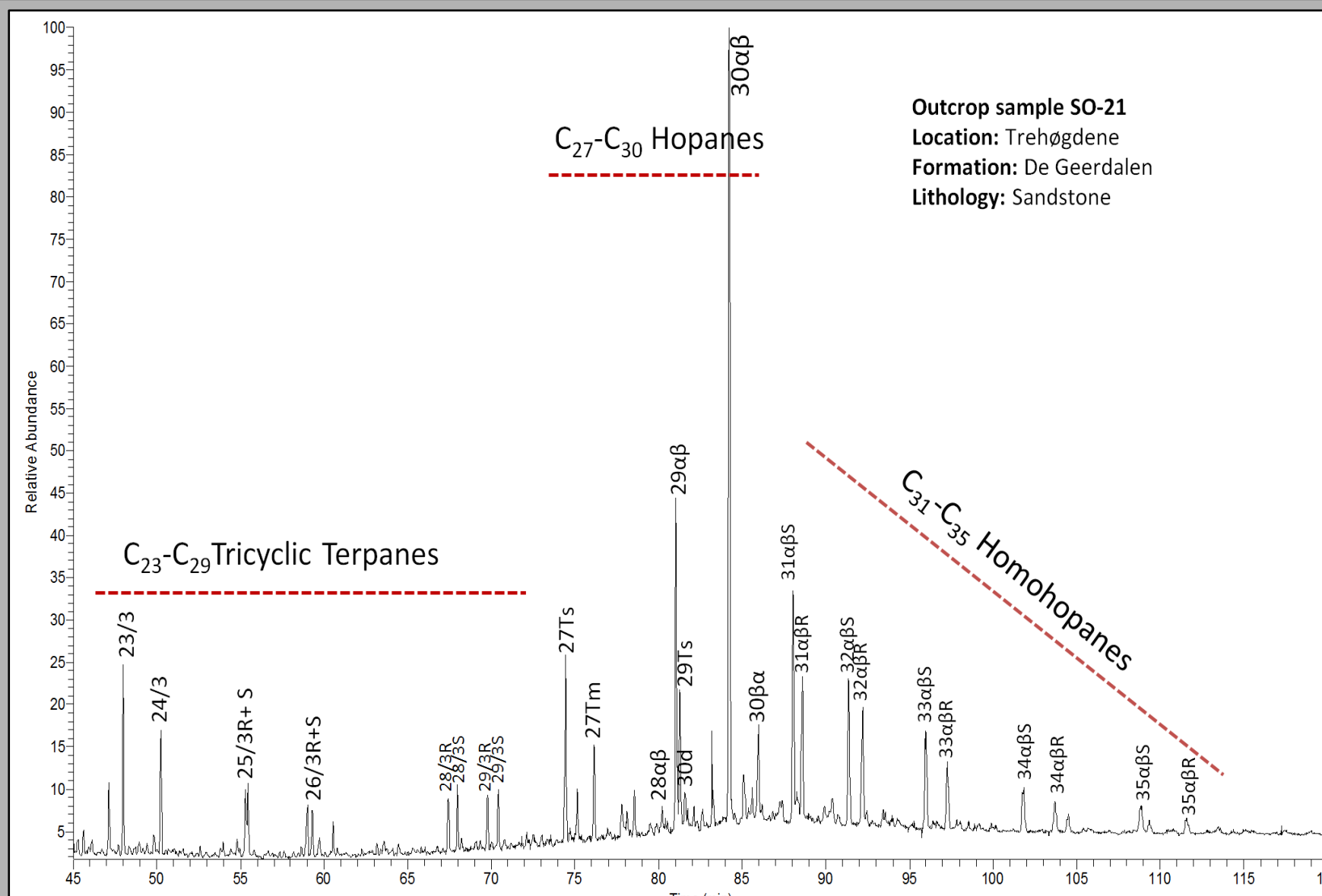


Fig. 10: m/z 191 mass chromatogram of whole extract from Svalbard with well developed 28/3 and 29/3-tricyclic terpenes. Such signatures are ubiquitous in the Barents Sea and normally taken to signify the importance of the Botneheia/Steinkobbe Fm.

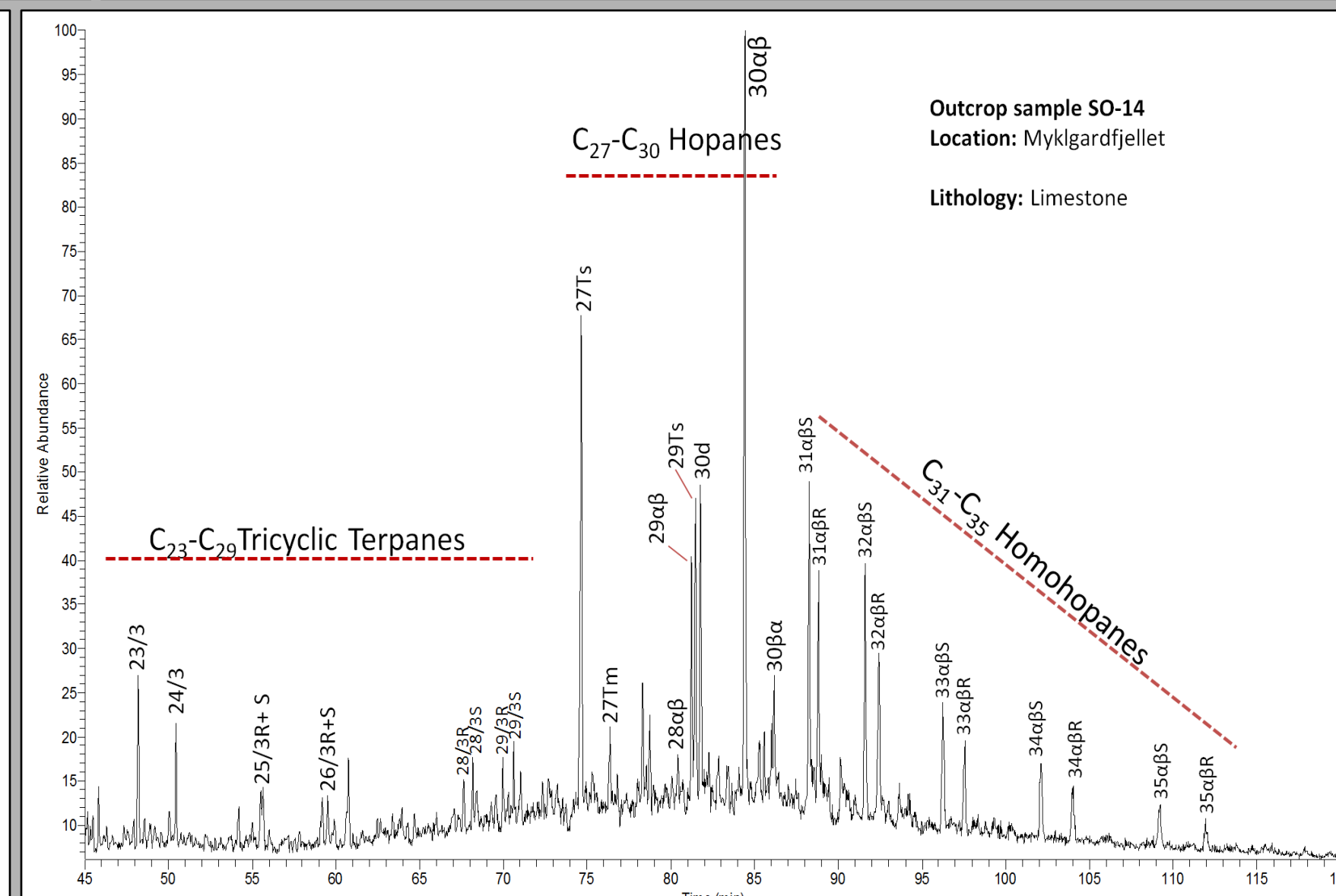


Fig. 11: m/z 191 mass chromatogram of whole extract from Svalbard representing extract from sample SO-14 (limestone). This signature clearly represents a different facies compared to Fig. 10. The high C₃₀ diaphane (peak 30d) is regarded, by Peters et al, 2005 as possible terrigenous marker which is also widely expected in coals. See also GC-FID of this sample in Fig. 6.

Summary

❖Extracts from outcrop samples collected from various locations at Svalbard were geochemically analysed to investigated the possible presence of migrated hydrocarbons in sandstones, mudstones and carbonaceous sediments.

❖Data from Rock-Eval, GC-FID and GC-MS on these samples reveal the presence of hydrocarbons that have been migrated from mature source rocks.

❖The GC-FID & GC-MS traces illustrate variation in organic facies of the source rocks that must have sourced these extracts.

❖This variation in facies spans from marine to terrestrial, thus the outcrops contain migrated hydrocarbons sourced at least from two facies. The first facies may have been generated from marine dominated Type II/III source. The second oil type is more waxy and characterized by having dominant n-alkane peaks in the range C₂₅ to C₃₀ (see Fig.6, sample SO-14). This later oil could have been generated from source rocks deposited in a more terrestrial/distal setting (e.g Agardhfjellet Fm).

❖Biomarker data also suggest that this could represent variation within Triassic Botneheia Fm. in this general region and the variable maturities suggest that we have in fact trapped oil expelled at very different Critical Moments.

❖These few examples, presented in this study, are meant to illustrate the usefulness of prospecting Svalbard for migrated oil signatures as a reference, both for understanding the petroleum systems in Svalbard, but also concerning the offshore analogues.

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Acknowledgements

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