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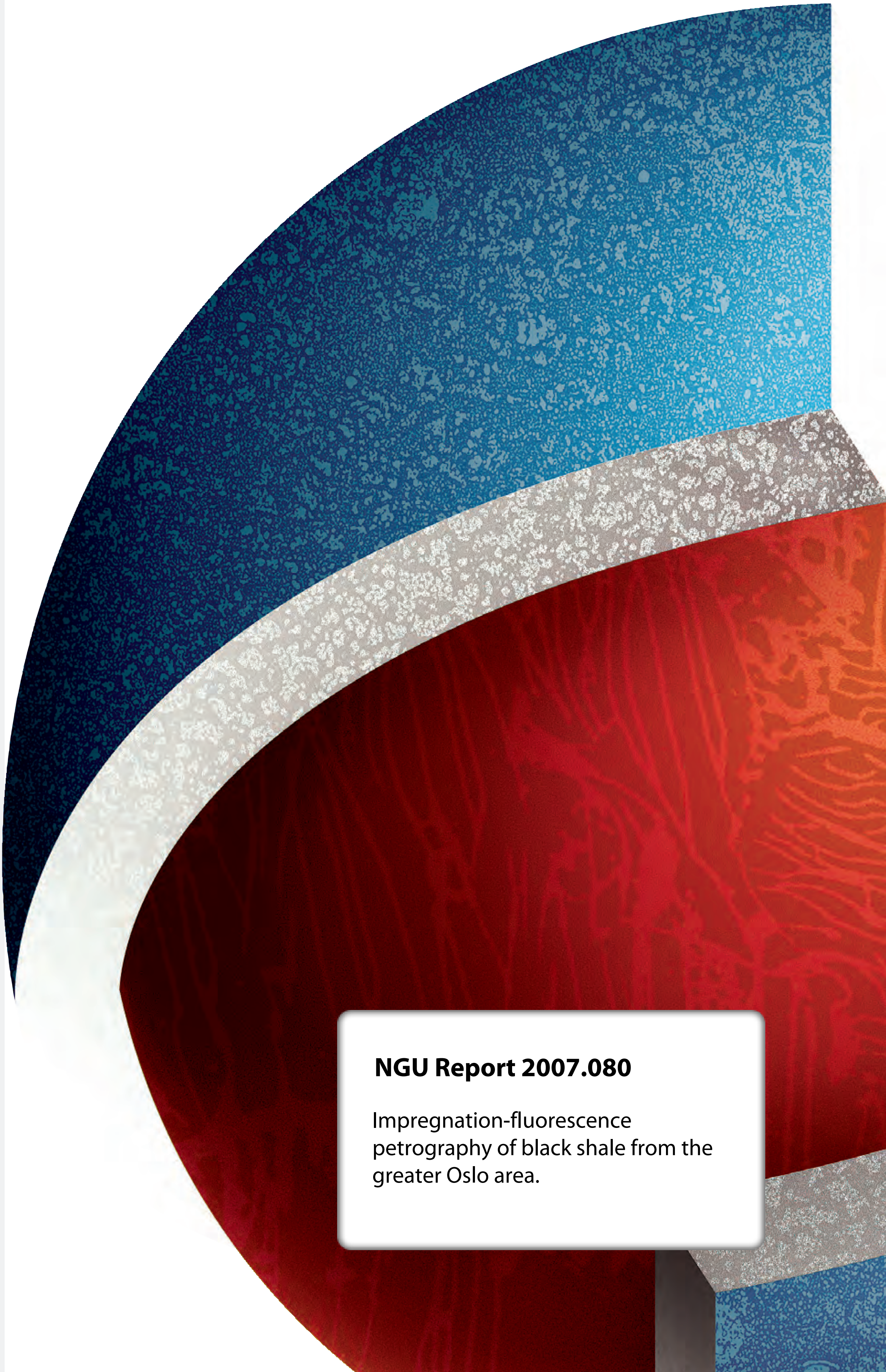

NGU Report 2007.080

Impregnation-fluorescence petrography of black shale from the greater Oslo area.

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REPORT

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Title:
Impregnation-fluorescence petrography of black shale from the greater Oslo area.

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Summary:

Extra thin sections have been made of Ordovician black (alum-) shale samples collected at two different localities and one waste pile in the greater Oslo area.

The matrix appears too be too fine-grained to be assessed even with extra thin sections of 15µm. To distinguish individual mineral grains and to study grain fabric, SEM is the appropriate instrument.

Thin section analysis reveals the presence of limonite encrustations and cracking of a very fine-grained black shale matrix, the deposition of secondary minerals on top of the limonite, as well as in cracks within the shale matrix.

However, impregnation-fluorescence petrography (IFP) provides an effective tool for the assessment of fluid porosity and permeability of the rock fabric, even though the sample materials were not collected specifically for this purpose. If this is taken care of e.g. by monitoring orientation and other properties during sampling, then IFP technique is able to provide data on fabric orientation and directed/channelized fluid transport.

Keywords:

black shale	thin-section petrography	impregnation-fluorescence
porosity	permeability	

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1. INTRODUCTION

The composition of black shale may vary locally, both regarding mineral content and geochemical composition.

To demonstrate this variation, Ordovician black shale from three different localities in and around Oslo have been analyzed with impregnation-fluorescence petrography on thin sections. Material was sampled at Konows gate (Oslo municipality), Slemmestad (two adjacent sites C and FE; Røyken municipality), and Taraldrud (Ski municipality), illustrated in Fig. 1 below.

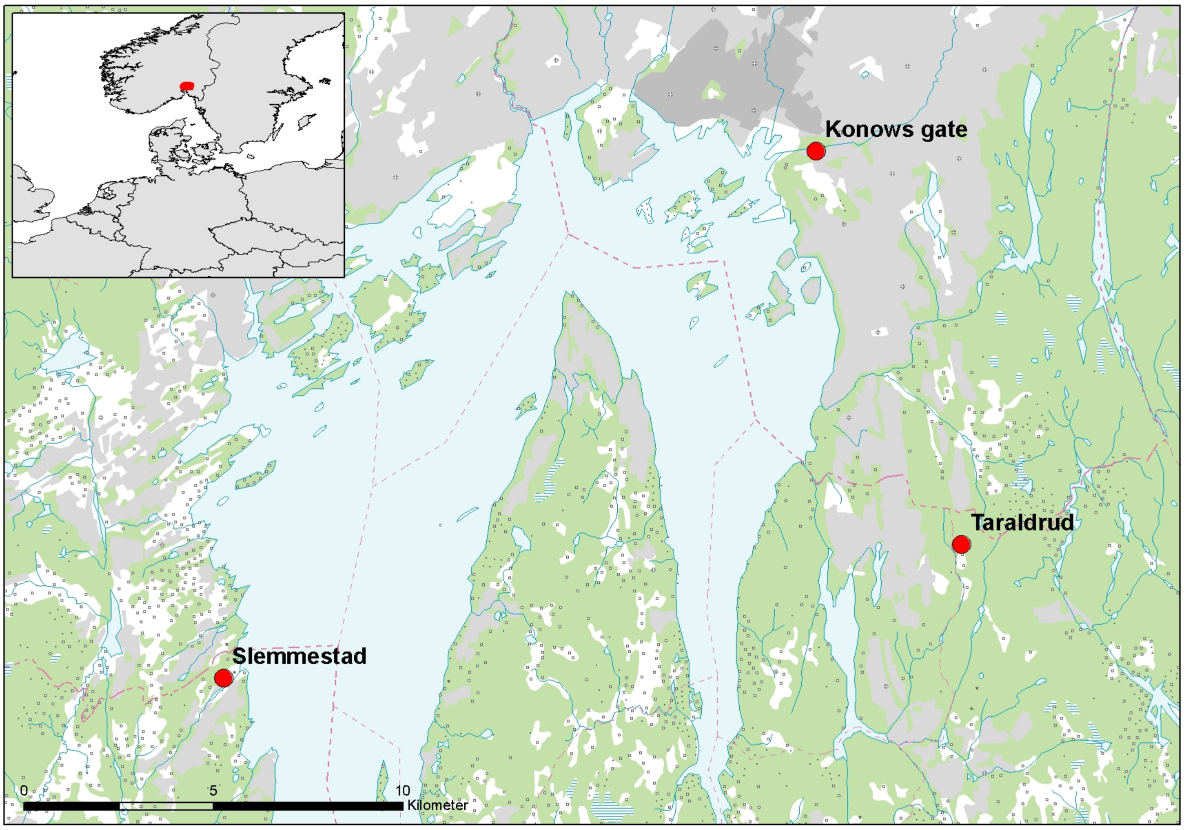


Figure 1: Sampling locations for black shale. Downtown Oslo located towards upper edge. (source: http://earth.google.com)

These materials have been assessed by optical petrography on fluorescence-impregnated thin sections, using a) plane-polarized light (PPL), b) crossed polarized light (XPL), and c) incident fluorescent illumination (FL). Occasionally, incident polarized light was used (i-PPL), to determine or confirm the presence of opaque minerals.

In addition, the same sample materials have been analysed for major and trace elements using a combination of whole rock analysis by XRF, LOI, Leco for total-S and total-C, and ICP-AES. As per time of this writing, geochemical data were not yet available. They will be presented in a future report.

2. ANALYTICAL METHODS

2.1 Sample origin, size, and representativity

The samples of black shale were collected at two localities within the black shale formation, knowingly at Konows gate 6-8 (Oslo municipality) from black shale tailings of local origin, and at Hermansåsen at Slemmestad (Røyken municipality), where black shale was sampled *in-situ* (two separate sampling sites labelled C and FE). The third site is a permanent pile of black shale tailings from a construction site in Akersgata (downtown Oslo), deposited on Precambrian basement rocks at Taraldrud /Ski municipality). All samples analysed in this report were collected from the surface.

For the black-shale samples studied here, representativity is not a problem with respect to matrix mineralogy, but in general, the mineral grains in shales, are to small to be subjected to grain-size counting statistics. However, different textural and micro-structural aspects related to veins, vugs, cracks and encrustations in these vary considerably in scale and may be of unknown representativity and thus difficult to quantify.

2.2 Thin section petrography

The black shale samples were vacuum impregnated with epoxy resin doped with fluorescent dye Hudson Yellow, essentially following the procedure described in Danish Standard 423.39 [1]. After full hardening of the epoxy, fragments were carefully trimmed to desired size with a closed-rim diamond blade, using a non-hydrous coolant. Thin sections for fluorescence-impregnation were prepared conform Danish Standard 423.40 [2], with minor adaptations. To compensate for the very fine-grained nature of the sample material, thin section thickness was reduced to 15µm, as opposed to the standard thickness of 30µm. Finally, a cover glass was affixed using UV-hardening single component acrylate glue.

Thin sections were studied in a Zeiss Axioplan-pol 2e Imaging petrographic microscope using polarization and fluorescence techniques, with magnifications ranging from 25× - 400×. Images were acquired with a Zeiss Axiocam HR camera at 1300×1030 non-interpolated scanned resolution or greater and stored at 24bpp colour depth in uncompressed .tif format.

3. RESULTS

3.1 Impregnation-fluorescence petrography

Four samples of black shale from three different locations in the Oslo region (Fig. 1) have been assessed by optical petrography on fluorescence-impregnated thin sections, using a) plane-polarized light (PPL), b) crossed polarized light (XPL), and c) incident fluorescent illumination (FL). Occasionally, incident polarized light was used (i-PPL), to determine (or confirm presence of) opaque minerals. These abbreviations are also used in Appendix 1, containing thirteen figures (Figs. 2-14) showing selected features from four analyzed fluorescence-impregnated thin sections of black shale, arranged per sample locality.

Due to the very fine-grained nature of the black shale and its high content of organic matter, even extra thin 15µm sections (ie. only half the regular thickness) appeared very dark and dense with very little detail under the microscope. Furthermore, the general lack of matrix fluorescence illustrates the dense and impermeable character of the rock matrix in the sample material, except along cracks and fissures. Some curved or tortuous fluorescent features are filled in with more quartzose material; these may represent fossil burrows.

A few black shale fragments are wholly or partly coated by a limonitic encrustation from weathering and alteration, and are occasionally decorated with secondary minerals, forming sheaves or rosettes of prismatic to acicular crystal aggregates.

A few fragments can be seen to contain tiny flakes of detrital muscovite, their parallel orientation revealing an otherwise very difficult to discern oriented fabric, presumably S_0. Layering is thinly interspaced and occasionally folded in an open and undulating style, supposedly S_1. Crenulation has not been observed, but some fragments show evidence of extension by sets of multiple thin *en-echelon* cracks healed with quartz. Square voids suggest that at some moment in time, these cracks were open and accommodated cubiform crystals, possibly pyrite.

4. CONCLUSIONS

Thin section analysis reveals the presence of limonite encrustations and cracking of a very fine grained black shale matrix, the deposition of secondary minerals on top of the limonite, as well as in cracks within the shale matrix.

The matrix itself appears too fine-grained to be assessed with even extra thin sections of 15µm. To distinguish individual mineral grains and to study grain fabric, SEM is the appropriate instrument.

However, impregnation-fluorescence petrography (IFP) provides an effective tool for the assessment of fluid porosity and permeability of the rock fabric, even when sample materials were not collected specifically for this purpose. If this is taken care of e.g. by monitoring orientation and other properties during sampling, then IFP technique is able to provide data on fabric orientation and directed/channelized fluid transport.

5. REFERENCES

1. Danish Standard (2002): Concrete testing - hardened concrete - production of fluorescence impregnated plane sections. Danish Standard (423.39): pp 8.
2. Danish Standard (2002): Concrete testing - hardened concrete - production of fluorescence impregnated thin sections. Danish Standard (423.40): pp 12.

APPENDIX 1

Micrographs of selected features from fluorescence-impregnated thin sections of black shale, shown in Figures 2-14.

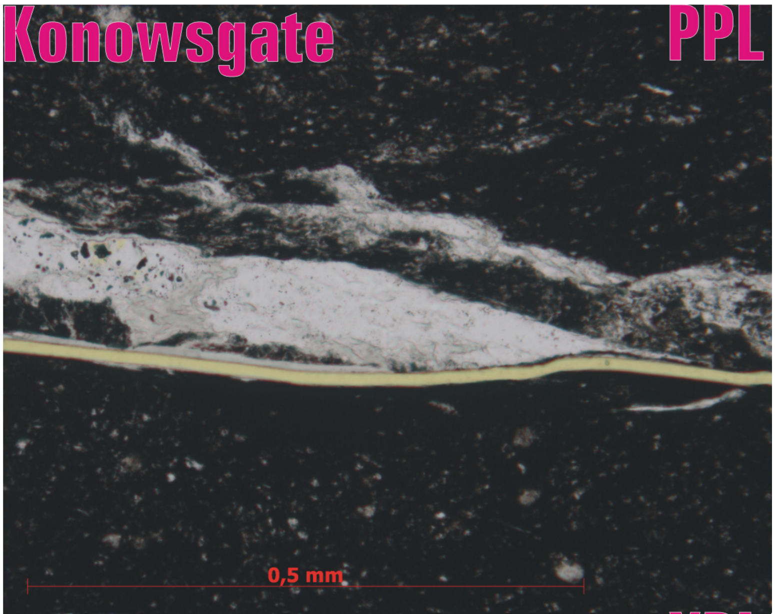
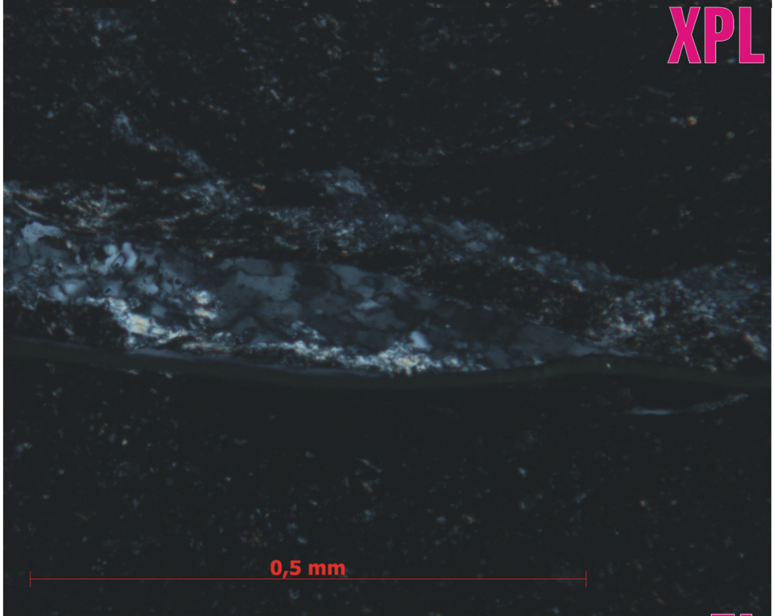
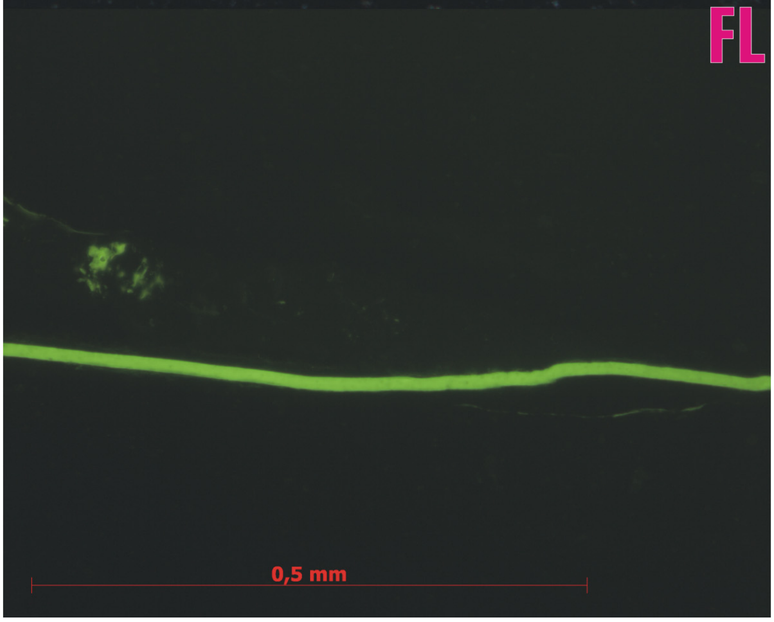


Figure 2: Black shale from Konowsgate. Micrograph showing a thin quartz vein or lens in black shale matrix in plane-polarized light (PPL). This might represent either a burrow fossil, or later veining.



Same view as above, in crossed polarized light (XPL). Note the presence of minor mica on the downside of the quartz vein.



Same view as both images above, in incident fluorescent illumination (FL). Note the porosity inside the quartz demonstrated by the fluorescence, and the absence thereof in the matrix.

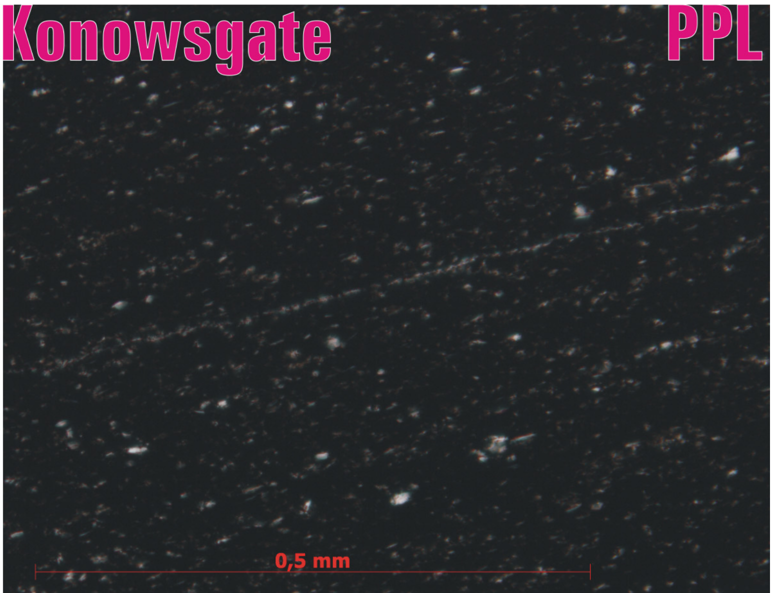
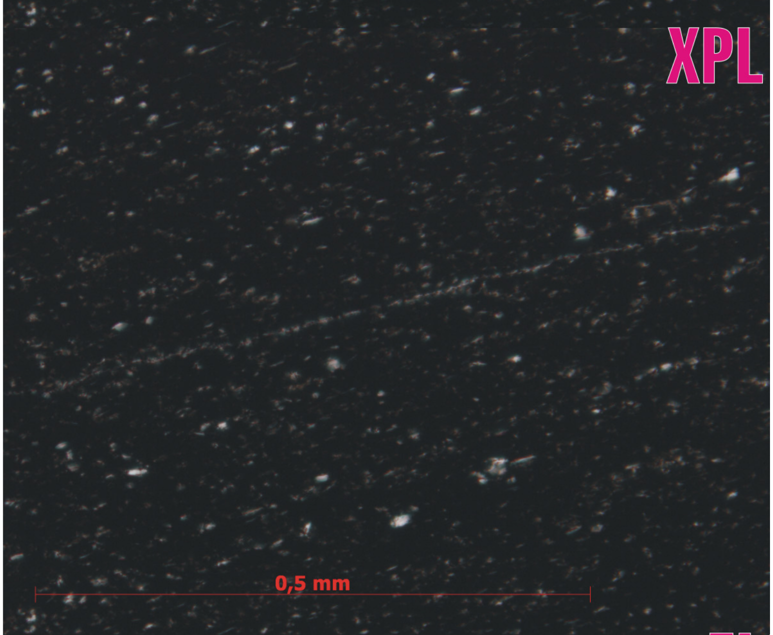
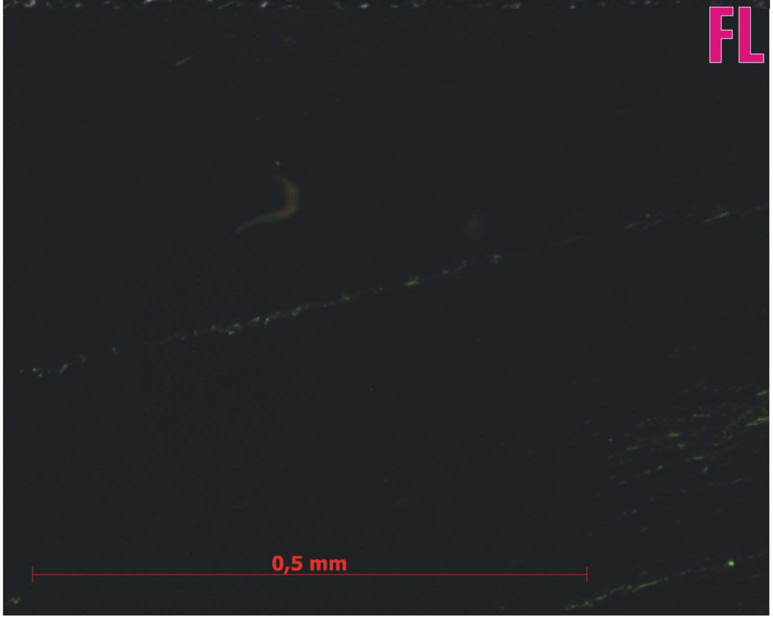


Figure 3: Black shale from Konowsgate. Micrograph showing detrital mica and quartz particles in black shale matrix, in plane-polarized light (PPL).



Same view as above, in crossed polarized light (XPL).



Same view as above, in incident fluorescent illumination (FL). Note the porosity in the thin vein running WSW-ENE.

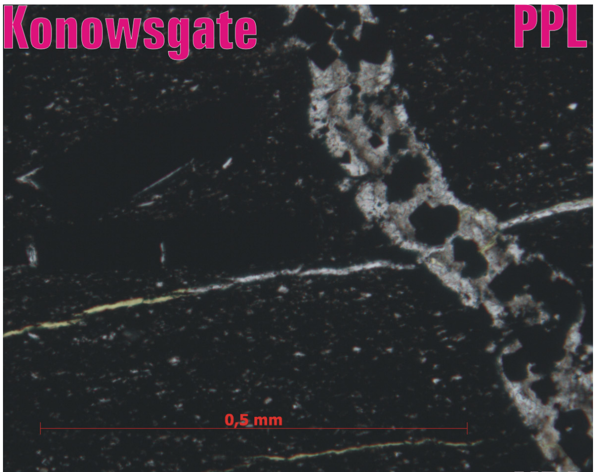
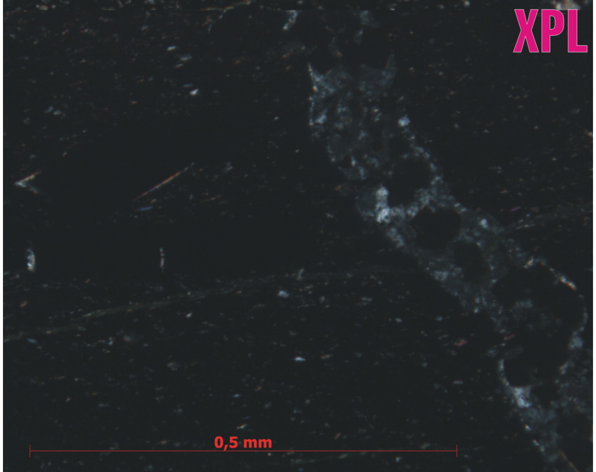
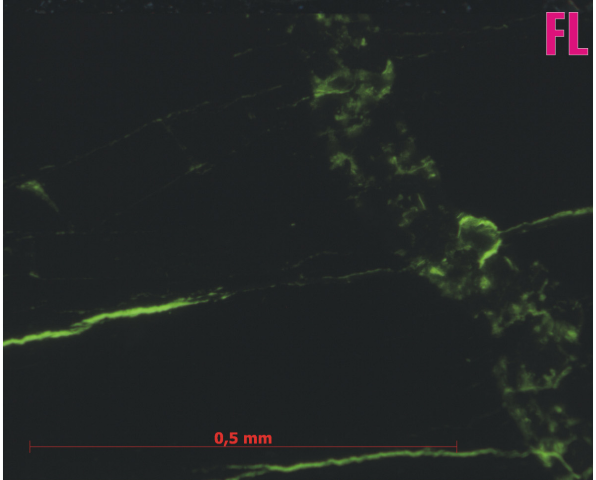


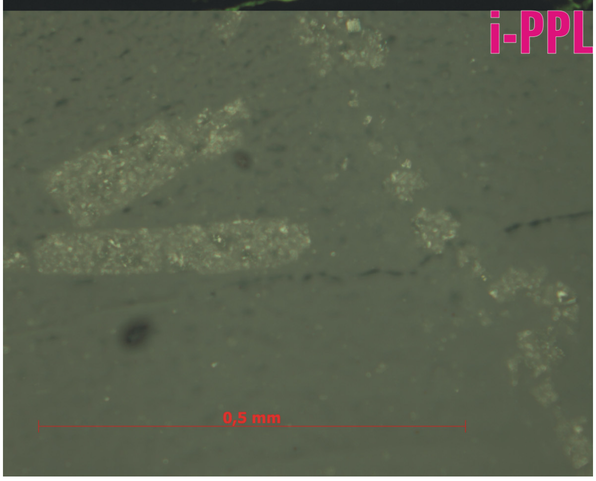
Figure 4: Black shale from Konowsgate. Micrograph showing a quartz-filled crack in black shale matrix, in plane-polarized light (PPL). Along its center, a bead-chain of opaque minerals occurs, forming more or less isometric grains..



Same view as above, in crossed polarized light (XPL).



Same view as above, in incident fluorescent illumination (FL). The quartz-filled crack has a higher porosity than the host material.



Same view as above, in incident plane polarized light (i-PPL). Even in an unpolished section, the opaques can be identified as the sulphide pyrite.

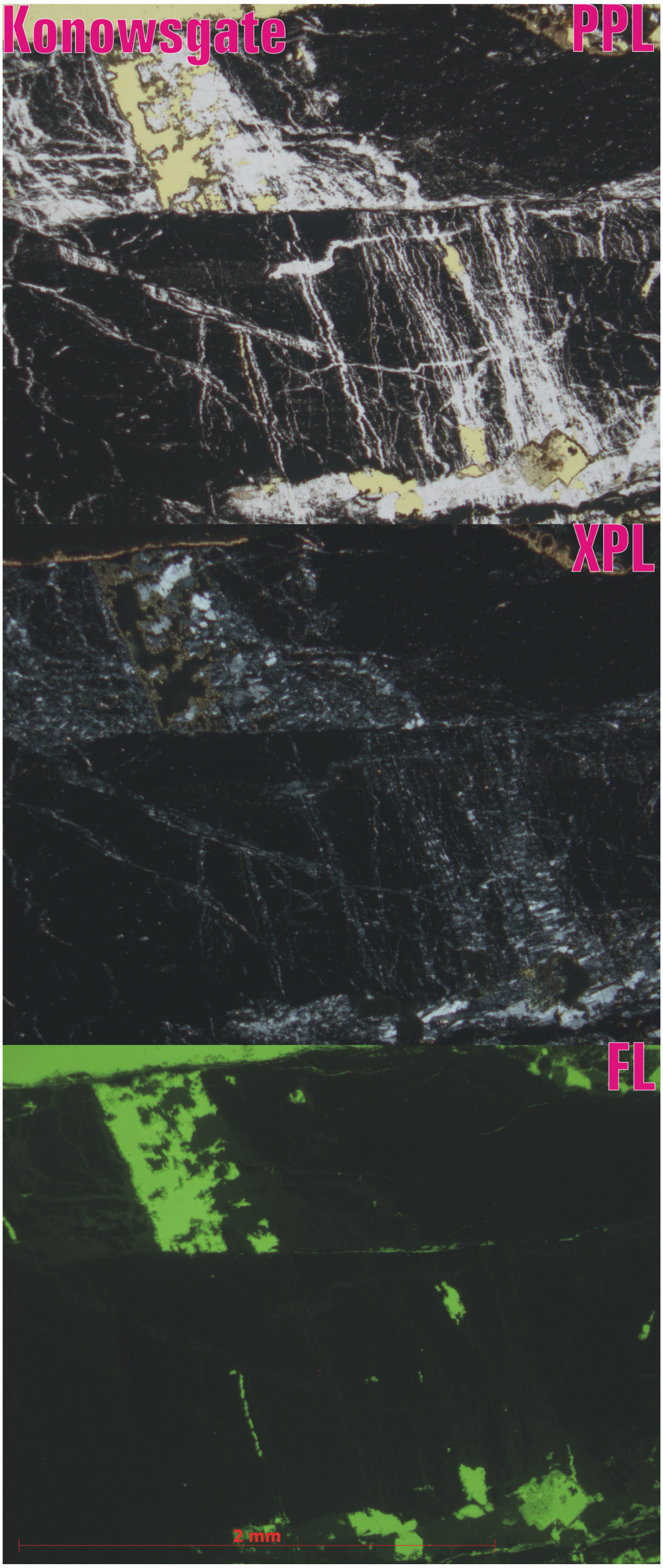


Figure 5: Black shale from Konowsgate. Micrograph showing *en-echelon* crack in black shale matrix, in plane-polarized light (PPL). The close interspacing of the *en-echelon* crack fabric implies that off-sets were small but frequent, and that the crack provided fluid access to the rock.

Same view as above, in crossed polarized light (XPL).

Same view as above, in incident fluorescent illumination (FL). Note the cubiform voids at lower left, possibly from weathered-away pyrite. Such large crystals can only form if the entire space is open at the time of deposit.

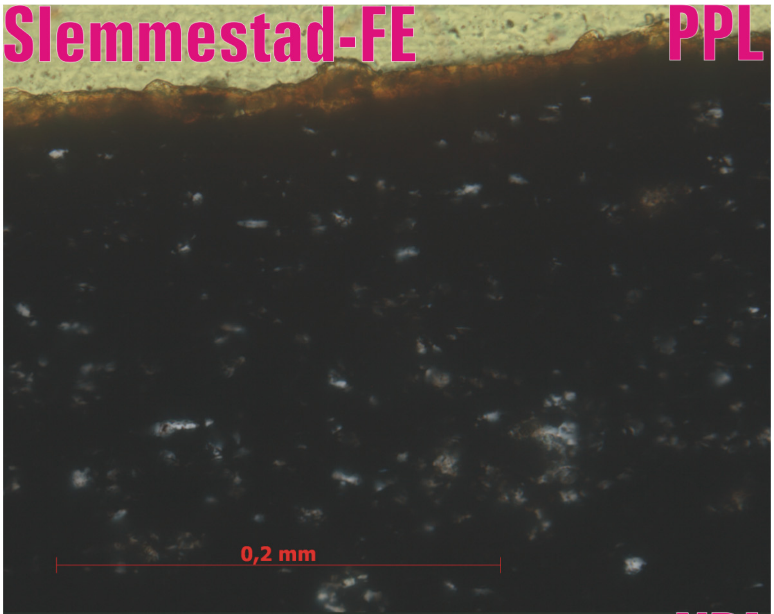
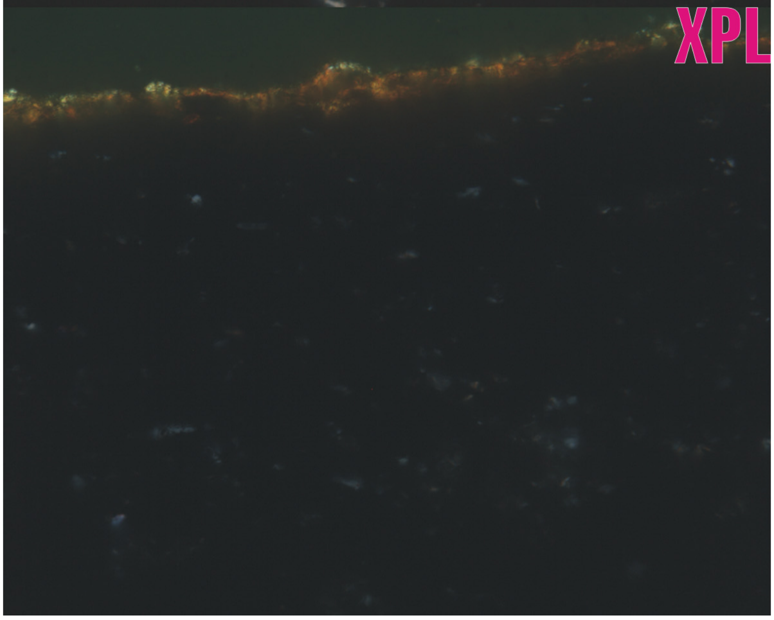


Figure 6: Black shale from Slemmestad, iron sludge. Micrograph showing limonite encrustation on black shale fragment, in plane-polarized light (PPL).



Same view as above, in crossed polarized light (XPL).

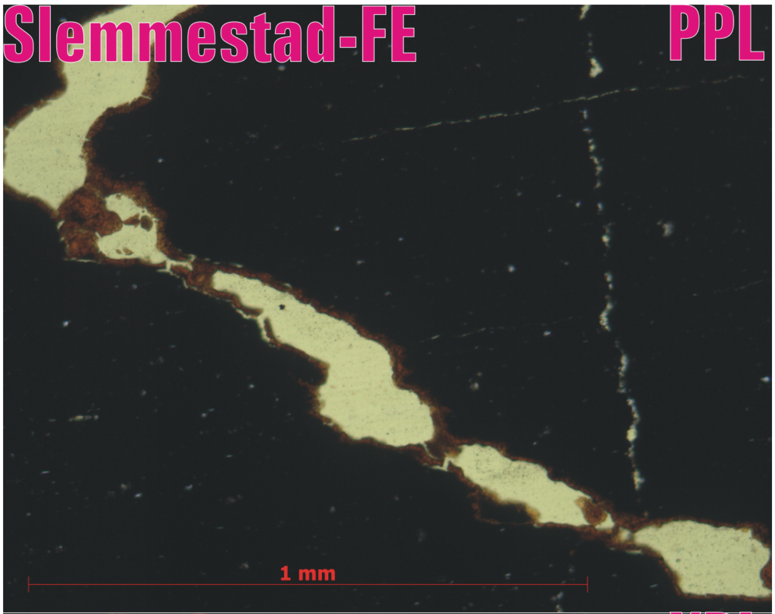
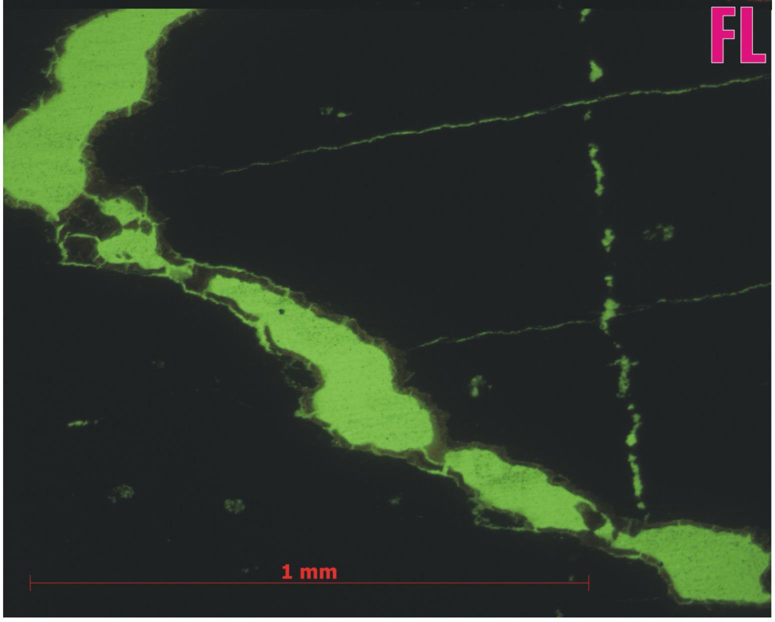


Figure 7: Black shale from Slemmestad, iron sludge. Micrograph showing limonite encrustation on black shale fragment, in plane-polarized light (PPL). The limonite can be seen to cement fragments together.

Same view as above, in crossed polarized light (XPL).



Same view as above, in incident fluorescent illumination (FL). Note the veining and layer-parallel cracking in the upper right fragment, as well as the exsiccation cracking in the limonite crust towards the left.

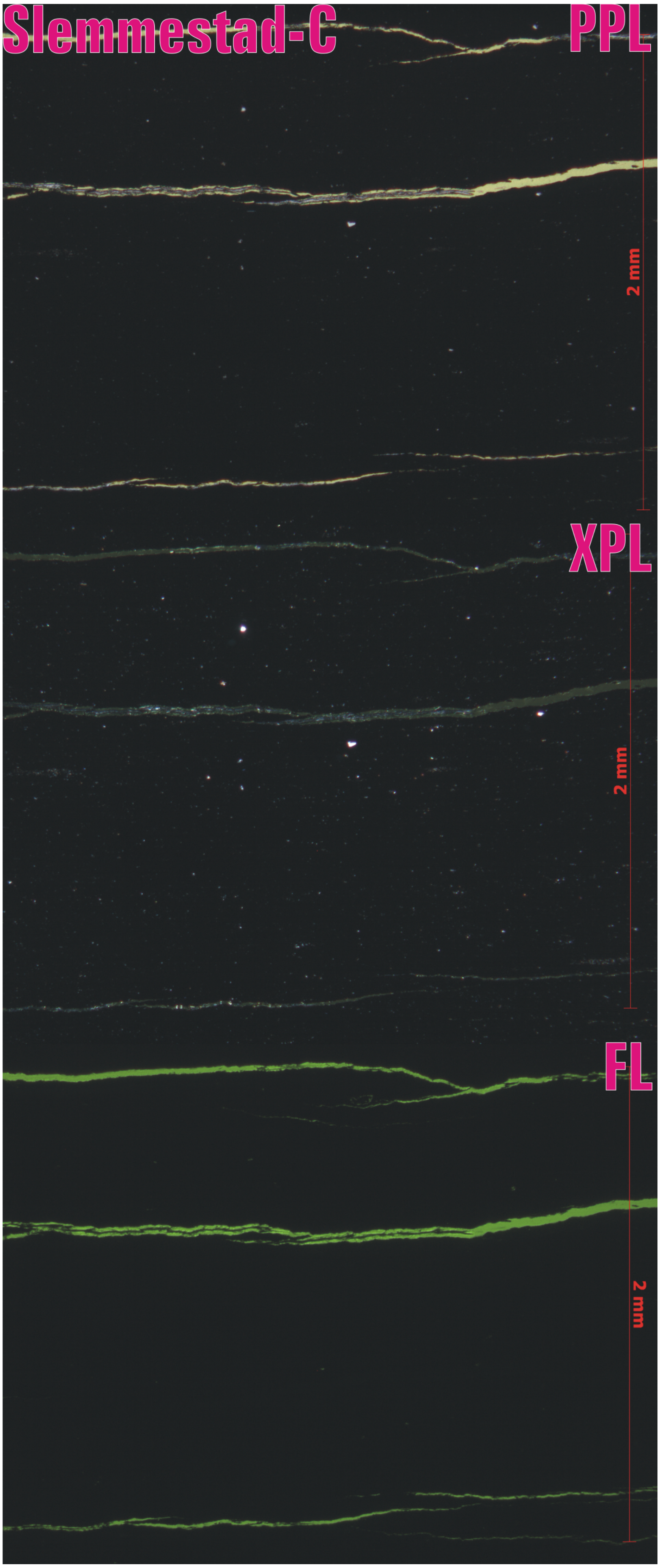


Figure 8: Black shale from Slemmestad. Micrograph showing *en-echelon* cracks in black shale matrix parallel to layering (S_0?), in plane-polarized light (PPL).

Same view as above, in crossed polarized light (XPL).

Same view as above, in incident fluorescent illumination (FL). The central crack can be seen to carry material at its center.

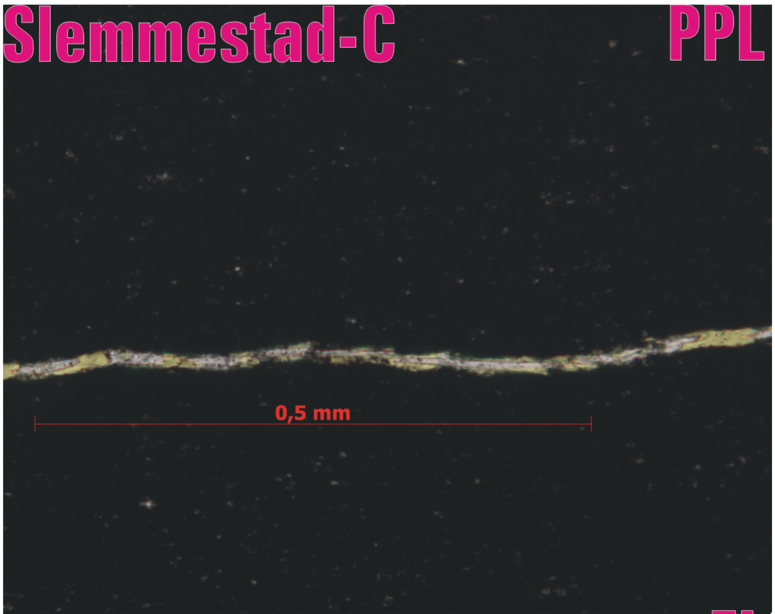
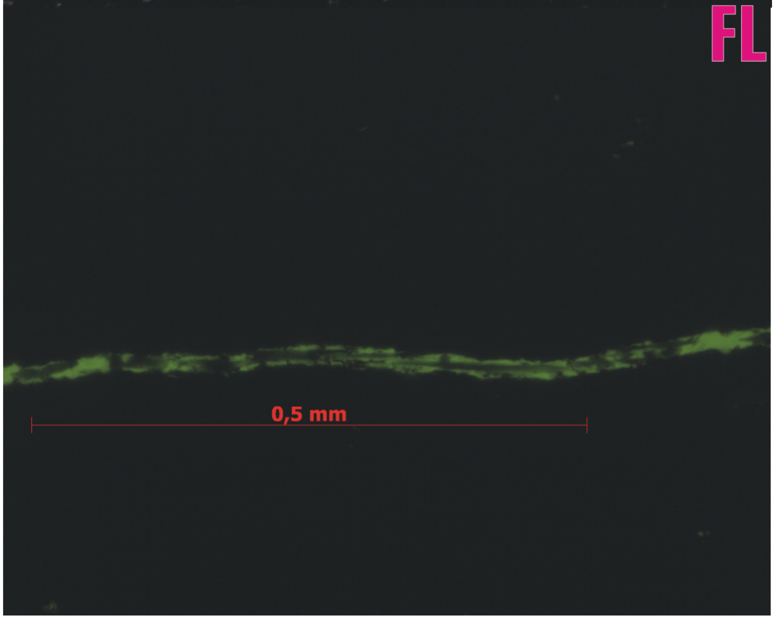


Figure 9: Black shale from Slemmestad. Detail of Figure 7, in plane-polarized light (PPL).



Same view as above, in incident fluorescent illumination (FL).

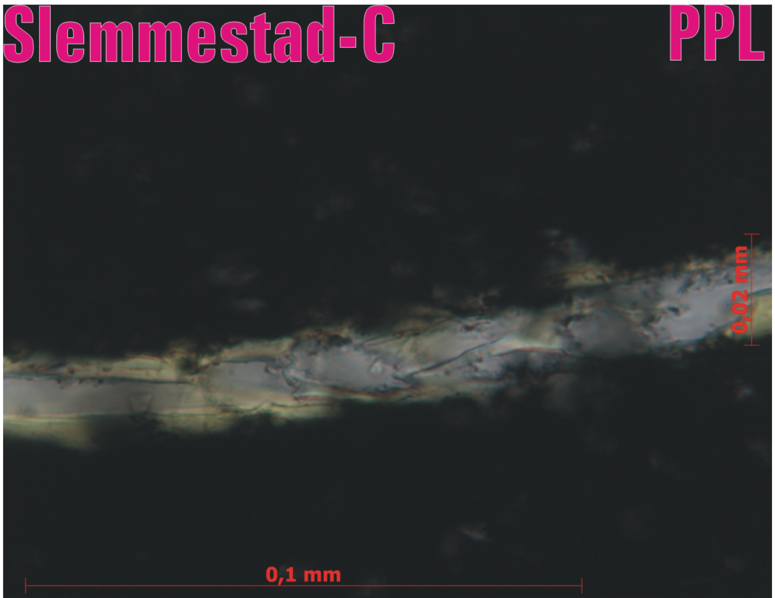
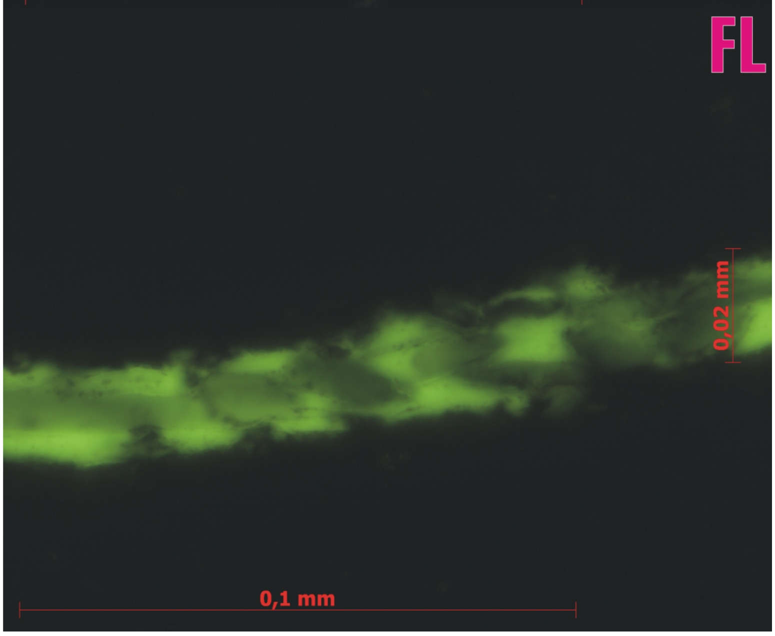


Figure 10: Black shale from Slemmestad. High magnification detail of Figure 8, in plane-polarized light (PPL). The material inside the crack is still difficult to identify.



Same view as above, in incident fluorescent illumination (FL).

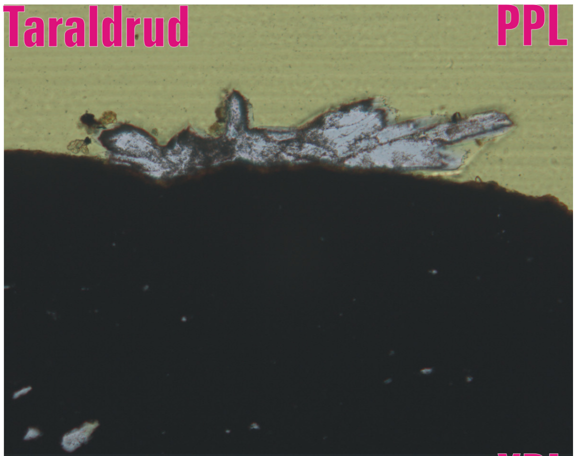
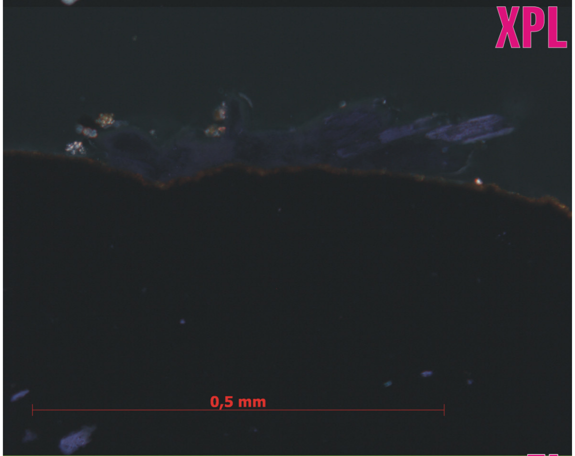
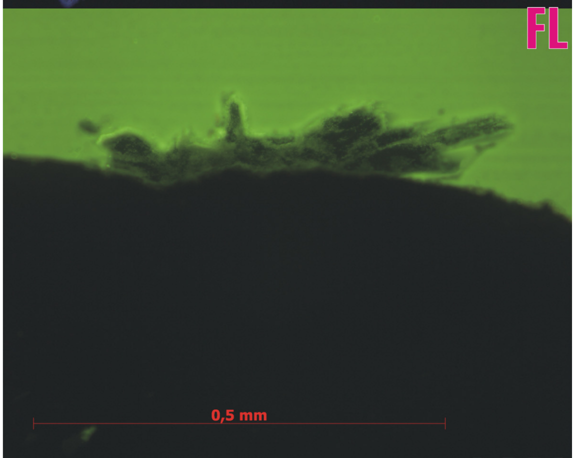


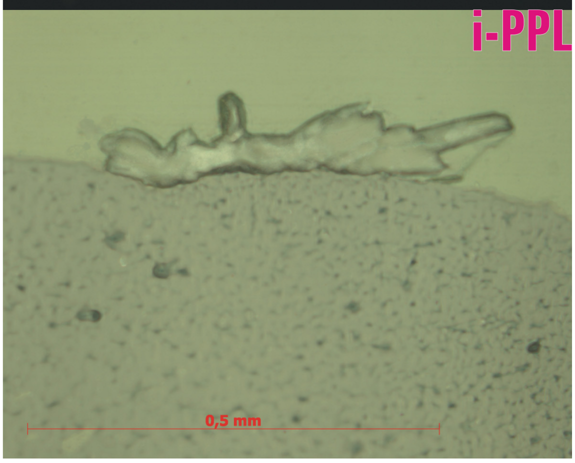
Figure 11: Black shale from Taraldrud. Micrograph showing secondary minerals on top of limonite-encrusted black shale matrix, in plane-polarized light (PPL).



Same view as above, in crossed polarized light (XPL).



Same view as above, in incident fluorescent illumination (FL).



Same view as above, in incident plane polarized light (i-PPL).

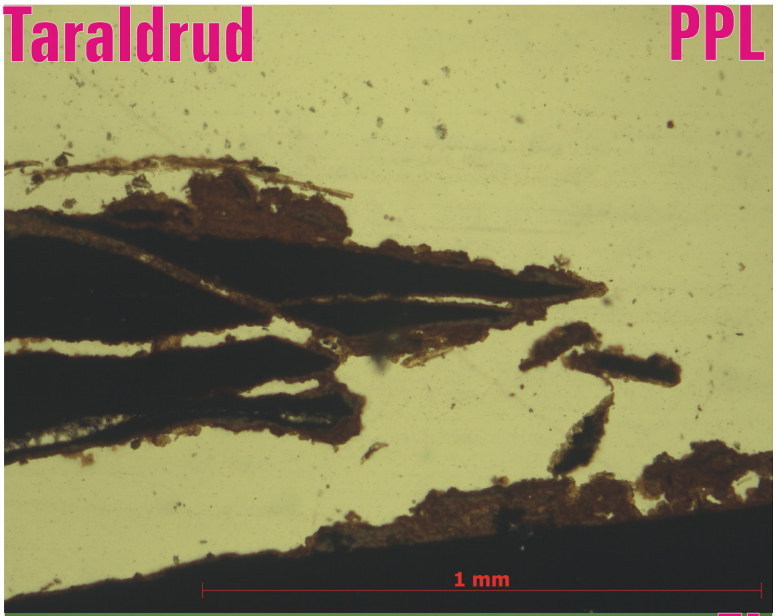
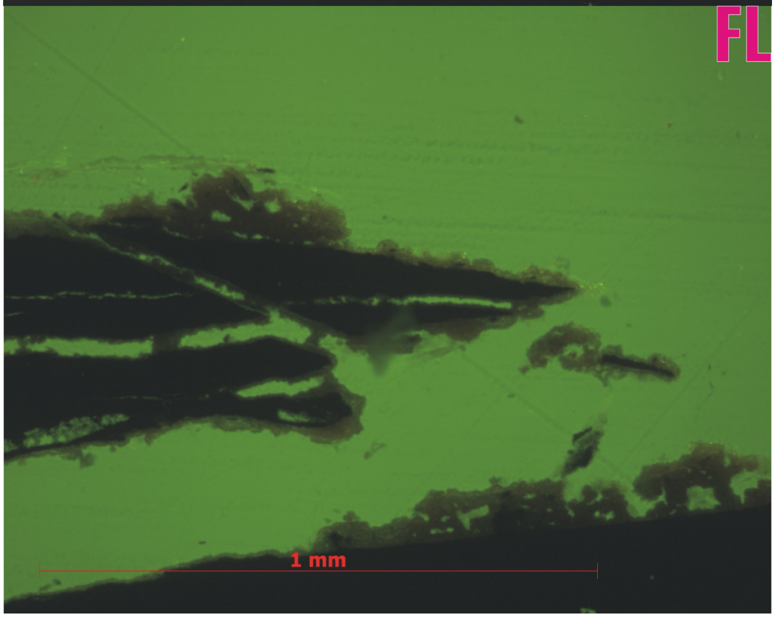


Figure 12: Black shale from Taraldrud. Limonite encrustation on cracked shale matrix, in plane-polarized light (PPL). Note several generations of limonite superimposed upon each other.



Same view as above, in incident fluorescent illumination (FL).

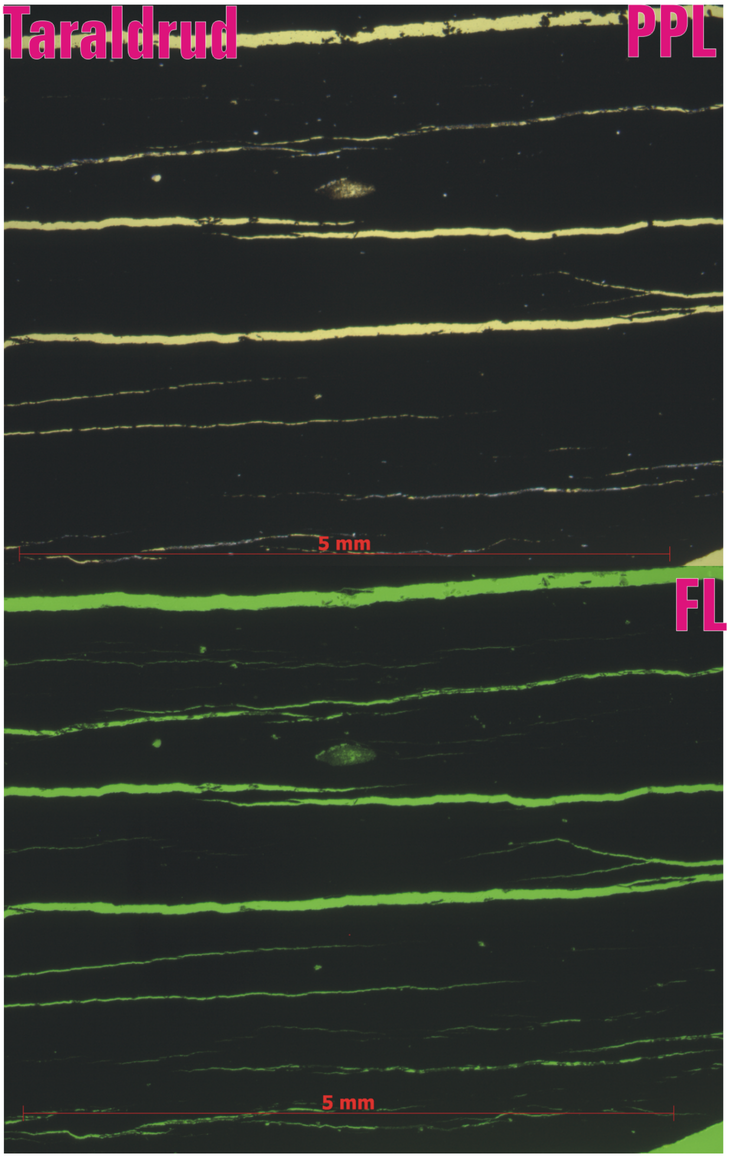


Figure 13: Black shale from Taraldrud. Micrograph showing *en-echelon* cracks in black shale matrix parallel to layering (S_0?), in plane-polarized light (PPL).

Same view as above, in incident fluorescent illumination (FL). Just above center, the observed porosity may indicate fossil remains of some sort.

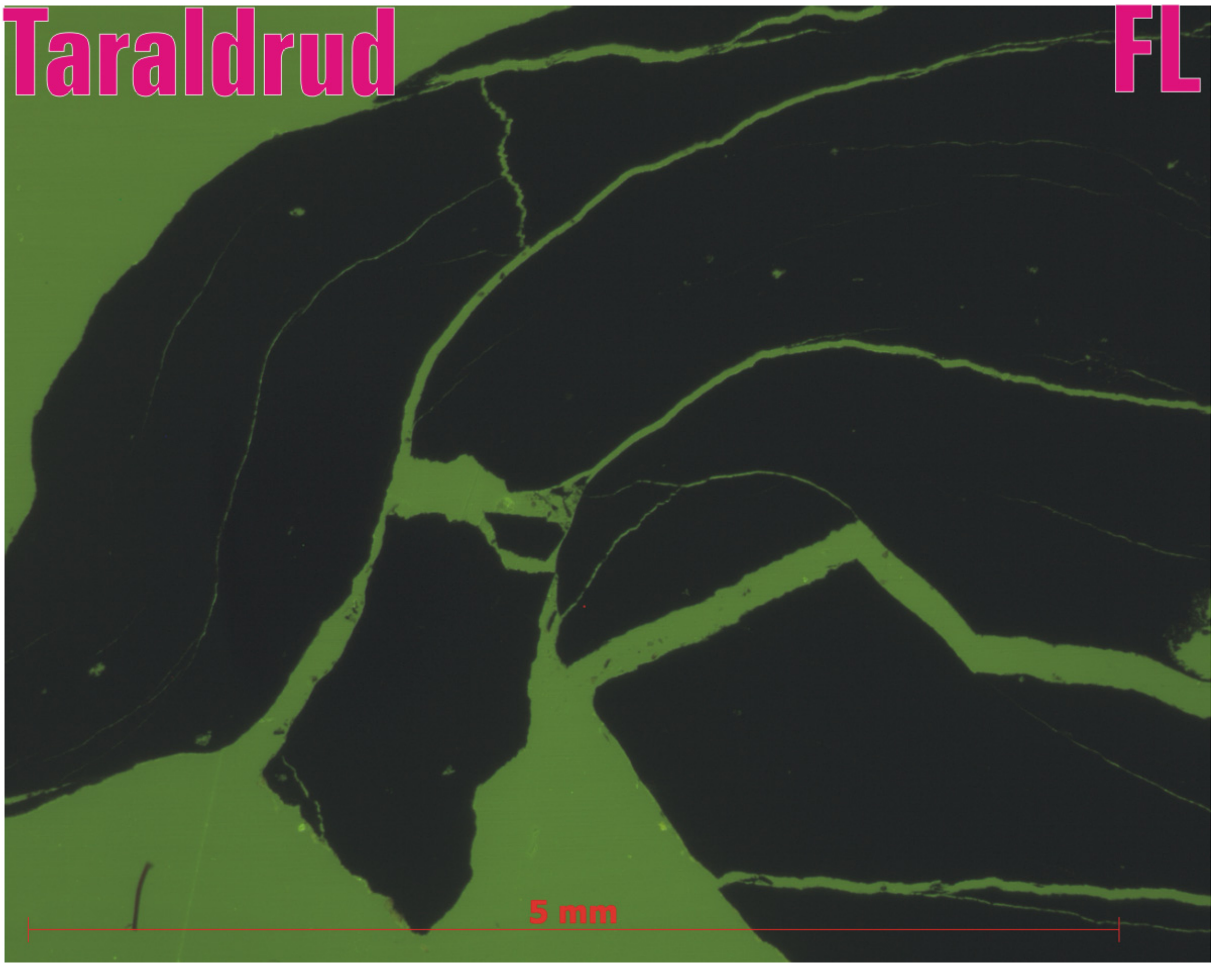


Figure 14: Black shale from Taraldrud. Cracks and cleavage revealing folding of the black shale matrix. Incident fluorescent illumination (FL).

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