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Characterisation of garnet,
Engebøfjellet rutile deposit

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REPORT

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Characterisation of garnet , Engebøfjellet rutile deposit

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Summary:

This report provides documentation of the Engebøfjellet eclogite and of the characteristics of garnet within it, including quantitative data on the chemical composition of the garnet, the amounts of garnet present and its grain-size distribution.

Based on image processing of thin-sections of rutile-ore-type eclogite, the garnet content generally varies from 25 to 40 wt. %, with an estimated average of 33 wt. %.

In representative rutile-ore-type eclogite the garnet grain-size is commonly in the range 100 to 250 microns (0.1-0.25 mm) and smaller, but larger garnet grains in the range 300-400 microns seem to occur fairly frequently.

Inclusions of other minerals in garnet are common, but the amounts of inclusions in representative "normal size" (less than 250 microns) garnet are generally regarded as low, although precise quantitative data is not available. In general, the amount of inclusions increases with garnet grain-size and may be considerable in the larger garnets.

Based on this information it is believed that high-quality garnet concentrates with garnet grain-size in the range 100 to 300 microns, could be produced from representative rutile-ore-type eclogite.

The documentation provided and the knowledge behind it represent highly relevant back-ground information for continued mineral processing trials in order to test the possibilities for making garnet concentrates of sufficient quality for various applications.

Keywords:	Industrial minerals	Eclogite
Garnet	Rutile	

Characterisation of Garnet in the Engebøfjellet rutile deposit

Report to Nordic Mining ASA by Are Korneliussen, Håvard Gautneb and Agnes Raaness, NGU

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1. Characterisation of core samples, illustrated by microphotographs and SEM-images
2. XRF and rutile analyses

1. INTRODUCTION

The Engebøfjellet rutile/eclogite deposit was investigated by DuPont/Conoco in 1995-97 in collaboration with NGU; in that project NGU's role was mainly to provide geological information about the deposit. All mineral processing, 3D-modelling of the deposit, etc, was carried out by DuPont.

The Engebøfjellet deposit is now being further developed by Nordic Mining ASA. NGU is supporting this project by providing geological information based on expertise obtained during the DuPont-project in the 1990s.

The purpose of this report is to provide information about the occurrence of garnet in the Engebøfjellet deposit. This report is to be followed up by a report focusing on rutile and the characteristics of rutile-ore-type eclogite.

Appendix 1 is an extensive visual documentation of rutile and garnet characteristics based on microphotographs and SEM-images, but does not give precise quantitative information on the garnet present, such as grain-size distributions, inclusions and micro-fractures.

2. PREVIOUS INVESTIGATIONS

The geological characteristics of the Engebøfjellet rutile deposit are summarised by Korneliussen et al. (2007).

The mineralogy of the eclogite is described in detail by Dr Muriel Erambert (University of Oslo) who wrote Appendix 5 in Korneliussen et al. (1998), which is a report on the geology of the Engebøfjellet deposit. Electron microprobe analyses available in that report and summarised in Appendix 2, show that the Engebøfjellet garnet is fairly iron-rich (avg. 28.3 % FeO_t) but also that it contains a fair amount of calcium (avg. 8.5 % CaO) and magnesium (avg. 3.8 % MgO). Average garnet end-members are Alm 59.8, Spe 1.6, Pyr 14.9, Gro 20.3 and And 3.5.

Other garnet analyses are also available from www.ngu.no in a presentation on Engebøfjellet (Korneliussen & Raaness 2005).

Basic information about garnet as an industrial mineral is provided by Harben (2002).

3. RUTILE ORE CHARACTERISTICS

The cut-off for "rutile ore" has tentatively been set to 3% TiO_2 as illustrated in Fig. 1. Depending on properties related to mineral processing as well as other factors, it might well be that this limit has been set too low or too high. However indicative, what is above the stippled red line in Fig. 1A is rutile ore to be mined and what is below the line should be avoided in a mining operation, i.e. sorted out in one way or another.

Garnet is intended to be a by-product or co-product in a rutile mining operation and will be produced from the same rock as the rutile. As for rutile, successful development of garnet mineral processing is crucial.

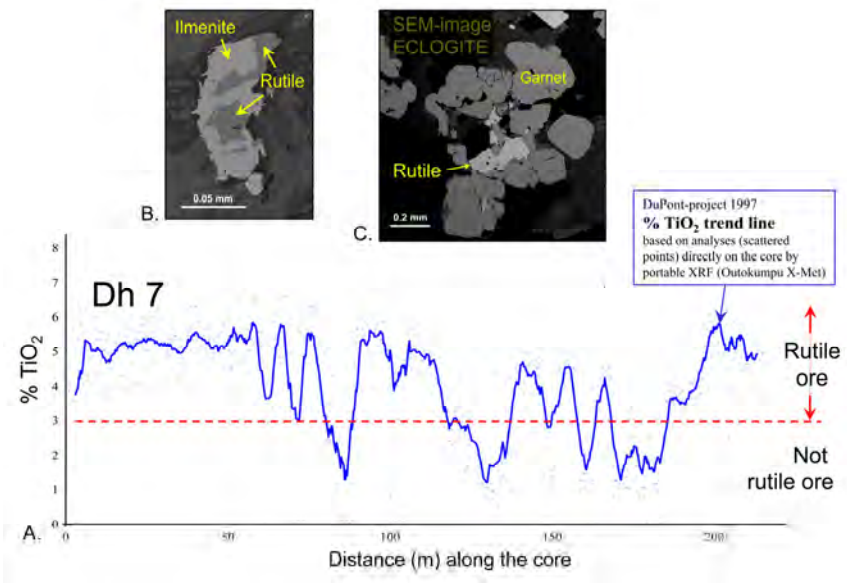


Fig. 1: (A) Illustration of TiO_2-variation along a borehole in relation to assumed marginal rutile grade (stippled line). (B) SEM-image showing rutile that is heavily altered to ilmenite. (C) SEM-image showing rutile and garnet in representative ore-type eclogite.

The petrographic character of the garnet and rutile shown in Fig. 1C is believed to be representative for large volumes of rutile-ore eclogite. Rutile is interstitial to garnet and other silicates, fingering in between the silicates, with a highly variable grain-size. Garnet tends to occur as well-crystallised grains, often rounded and usually with minor inclusions of other minerals. Commonly the garnet grain-size in rutile-ore eclogite tends to be in the range 100 to 300 microns (0.1-0.3 mm), although there are considerable variations.

Extensive visual documentation of the mineralogical characteristics of the rutile and garnet are given in Appendix 1.

Retrograde alteration of eclogite is a factor that should be carefully considered; for further explanation of this phenomenon see also Korneliussen et al (1998) and (2007) as well as the Engebøfjellet presentation available at www.ngu.no.

During retrograde alteration of eclogite rutile tends to alter to ilmenite; such altered rutile is shown in Fig. 1B. For most rutile-ore eclogite the overall effects of retrograde alteration are believed to be minor, i.e. a relatively small amount of the rutile present has been altered to ilmenite.

In the DuPont-project a "rutile analytical procedure" was used to quantify the amounts of ilmenite present in the rock and thereby the effects of retrograde alteration. This subject is to be further discussed in a coming report to Nordic Mining ASA focusing on rutile, as the present report is to focus on garnet.

During the DuPont-project more than 100 core samples (usually 10m core sections) were analysed by XRF giving $TiO_{2\ total}$ and ICP-AES giving $TiO_{2\ acid\ soluble}$. Acid-soluble TiO_2 indicates ilmenite, and the amount of rutile determined by this so-called "rutile analytical procedure" is

% Rutile = % $TiO_{2\ total,\ XRF}$ - % $TiO_{2\ acid\ soluble,\ ICP\text{-}AES}$

This method is indicative since it does not take into account $TiO_{2\ silicates}$, which are minor (~ 0.1 % TiO_2, situated within the crystal lattice of the minerals).

In most eclogite samples (usually 10m core sections) analysed (Appendix 2), $TiO_{2\ rutile}$ is close to $TiO_{2\ total}$, indicating that the effects of retrograde alteration on rutile are minor in most cases, while in other samples this effect might be considerable.

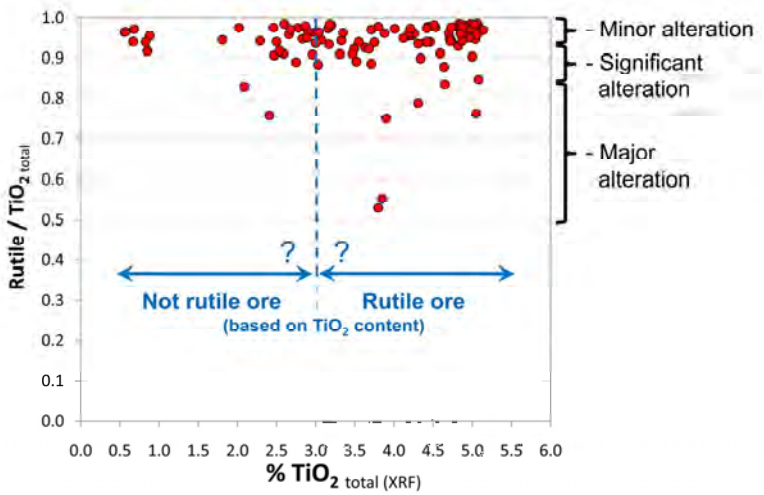


Fig. 2: TiO_2-rutile relationships and the effects of retrograde alteration on rutile/TiO_2-ratio, based on data in Appendix 2.

Fig. 2 illustrates the TiO_2 vs. Rutile/TiO_2 relationships for samples analysed by the rutile analytical procedure. The X-axis in the diagram show the TiO_2-variaton, which is normally used to indicate rutile ore grade; in this case 3 % TiO_2 is set to distinguish between rutile ore vs. not-rutile ore. The Y-axis shows the Rutile/TiO_2-ratio; for samples plotting close to the Rutile/TiO_2=1 line, the effects of retrograde alteration on rutile are minor. Alteration effects on rutile become larger with the distance of the samples from the line.

It is probable that more than 90% of the TiO_2 present in ore-grade eclogite (with more than 3 % TiO_2) occurs as rutile. However, there are large local variations.

Effects of retrograde alteration on garnet are minor.

4. ECLOGITE MINERALOGY

New samples taken from old cores in 2008 are described in detail in Appendix 1. This information gives extensive visual mineralogical-textural information on Engebøfjellet garnet as well as on the characteristics of the rutile.

Some key points based on Appendix 5 (by Muriel Erambert) in Korneliussen et al. (1998):

- The eclogites from Engebøfjellet are, in general, fine-grained rocks, either as a result of strong eclogite-facies deformation or due to lack of complete recrystallisation.
- Textures observed in the Engebøfjellet eclogite are characteristic of those displayed during the transition from gabbro to coronite to eclogite (see the detailed explanation in the report referred to). This textural evolution reflects the extent to which the rocks have been subject to deformation during eclogitisation.
- Fluid-rock interactions were frequent at all stages in the history of these rocks: abundant volatile-bearing phases characterize the eclogite parageneses (amphibole, phengite, clinozoisite, carbonate, and apatite) and retrogression is dominated by amphibole + plagioclase symplectites.
- Eclogite-facies veins containing quartz, omphacite, garnet, carbonate, amphibole, pyrite (less than 1 %) and rutile, are common, indicating a high fluid pressure during peak metamorphism.

GARNET (see for Chapter 5 for more details)

- In mafic eclogites (ferro-eclogite, i.e. the rutile-ore eclogite) the modal abundance of garnet ranges from 25-30 to 40-45 % (by volume, visual estimate), while in the leuco-eclogite the garnet abundance is usually less than 20% (by volume).
- In recrystallized mafic eclogites garnet grains are generally small (< 0.3 mm), euhedral (well-developed crystal faces) to subhedral (partly developed crystal faces). In leuco- and layered eclogite, garnet size is variable and can reach 1 cm.
- Inclusions are common in many garnets (most commonly carbonate, rutile, quartz, omphacite and amphibole). Small garnets tend to have fewer inclusions than the larger garnets.
- Garnet is almandine-rich and often chemically zoned, reflecting incomplete chemical homogenisation during eclogitisation; rim compositions have the highest almandine component (i.e. highest iron content).

OTHER ECLOGITE MINERALS

- Clinopyroxene (omphacite) is the most common mineral in eclogite, followed by garnet and amphibole. The modal abundance commonly ranges from 20-30 % to 50-60% (by volume, visual estimate). It is pale to medium green. In fine-grained rutile ore-type ferro-eclogite it is generally small and often shape-oriented parallel to the eclogite foliation. In leuco- and some transitional eclogite the omphacite frequently form large porphyroblastic grains surrounded by normal-sized omphacite, garnet, etc.
- Amphibole is the third most common eclogite mineral after omphacite and garnet, its amount ranging from traces to major proportions. Porphyroblasts are common in leuco-/transitional eclogites and include garnet, omphacite, rutile, mica, clinozoisite and carbonate.

Composition range from subcalcic actinolitic hornblende to barroisite. Retrograde alteration tends to alter omphacite to amphibole (hornblende).

- Phengite and paragonite (white micas) are characteristic of leuco- and transitional eclogites, but minor/trace amounts are also found in mafic eclogites.
- Clinozoisite/epidote is abundant in the matrix from leuco-eclogites and occasionally in the mafic eclogites.
- Carbonate (dolomite/ankerite) is a common minor phase in most eclogite varieties, but may be very abundant in some samples.
- Quartz ranges from a few disseminated grains in the most ferro eclogites to being abundant in some layered and leuco-eclogites.
- Rutile is irregularly disseminated in eclogite; usually less than 3 wt. % in the leuco-eclogite, 3 wt. % and more in ferro-eclogite.
- Ilmenite is formed as an alteration of rutile during retrograde alteration, and is usually intergrown with rutile.
- Pyrite is common as an accessory mineral (less than 1 wt. %) as disseminated grains, particularly in ferro-eclogite.
- Apatite is a common accessory mineral.
- Zircon occurs rarely, as tiny inclusions in rutile and garnet.

Fig. 3: Fairly heterogeneous rutile ore-type eclogite with quartz-veins.

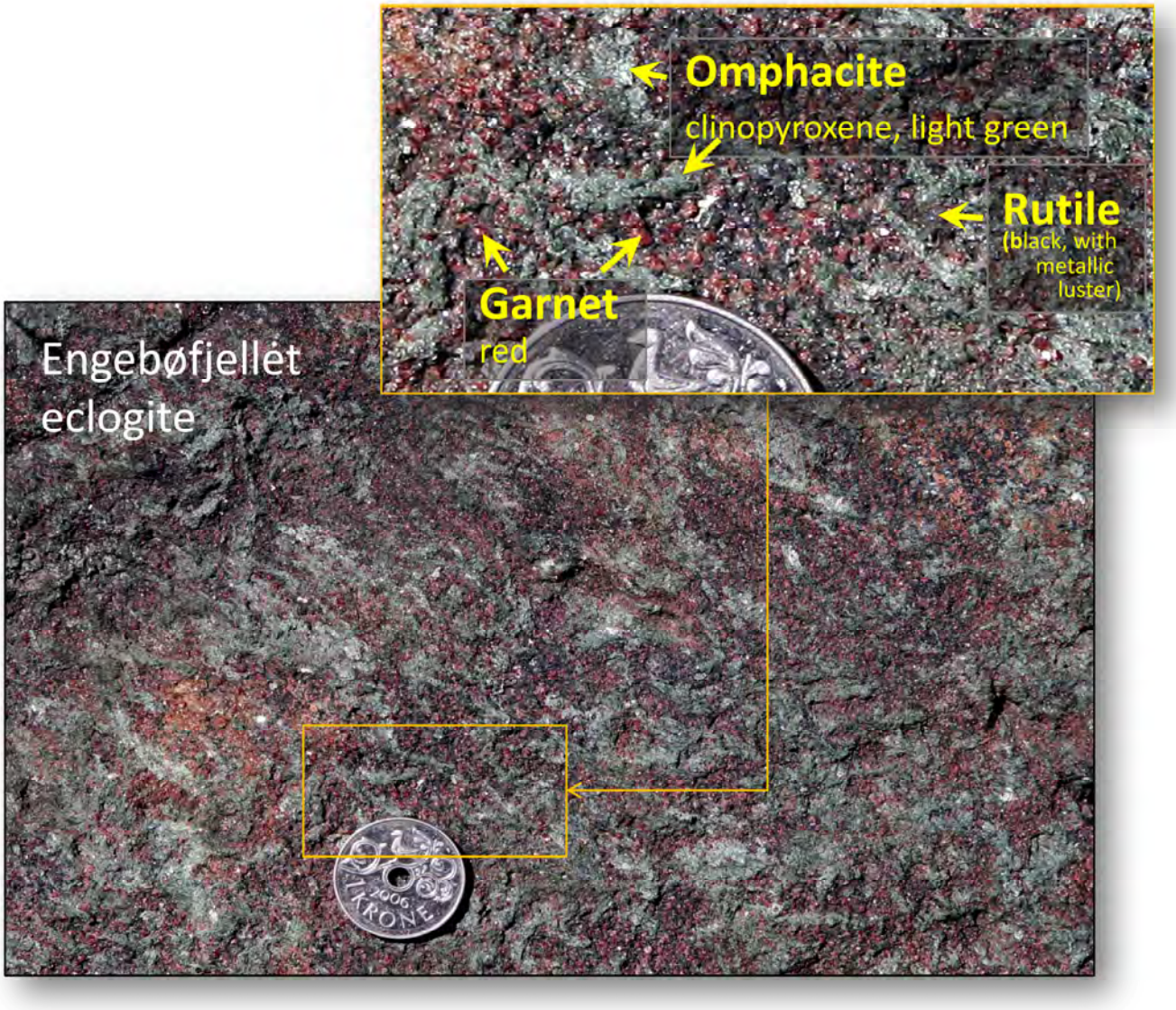


Fig. 4: Close-up photos of eclogite (leuco-/transitional eclogite, containing probably less than 2 wt. % rutile) with coarse-grained garnet crystals.

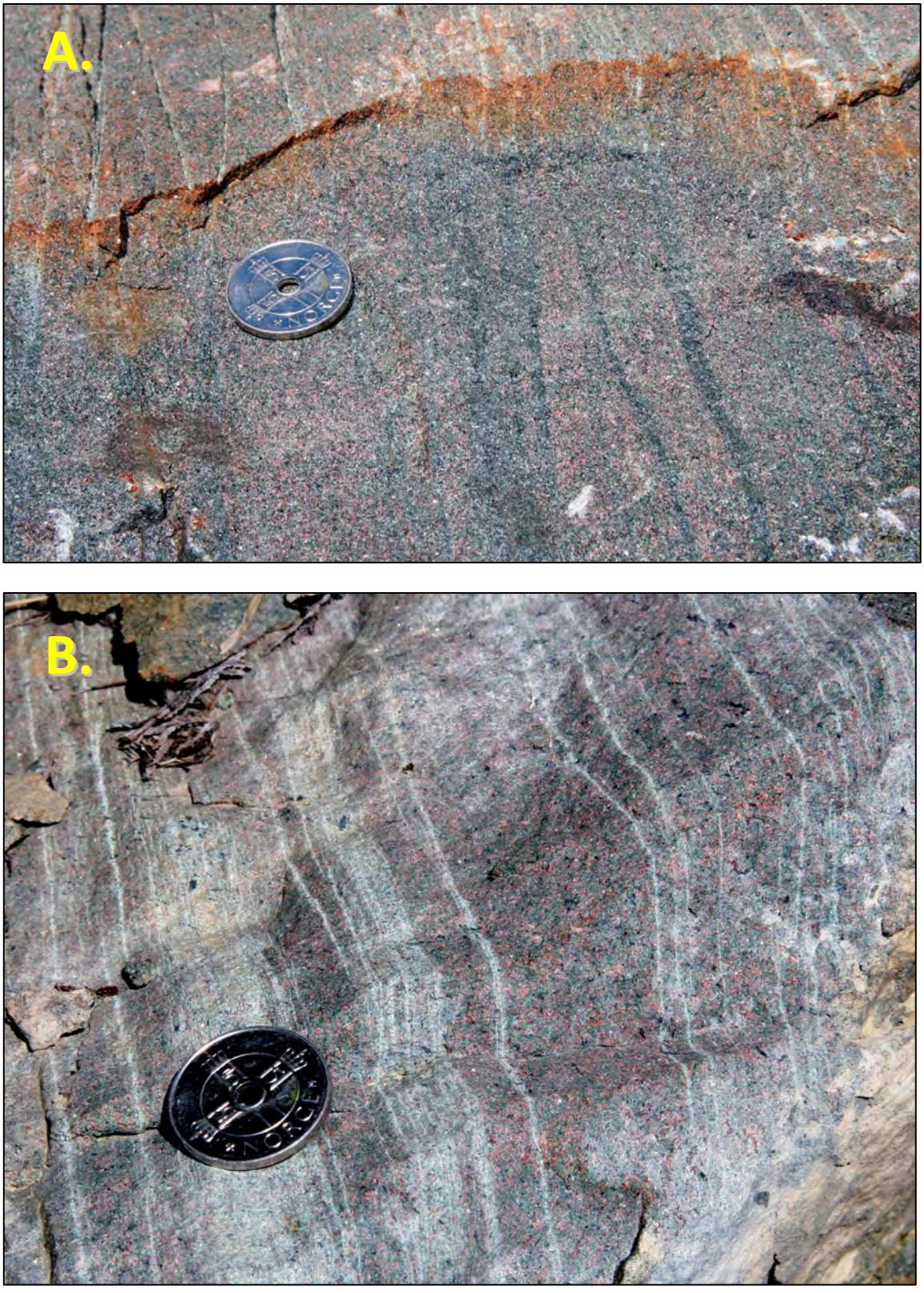


Fig. 5: Photos of fractures in eclogite (rutile ore type) with associated retrograde alteration. The retrograde alteration is dark green due to its amphibolitic composition; the white color of the alteration fractures zones in the lower photo is a weathering effect on the rock surface. There is a large complexity in the retrograde alteration of eclogite, which has not been studied in detail.

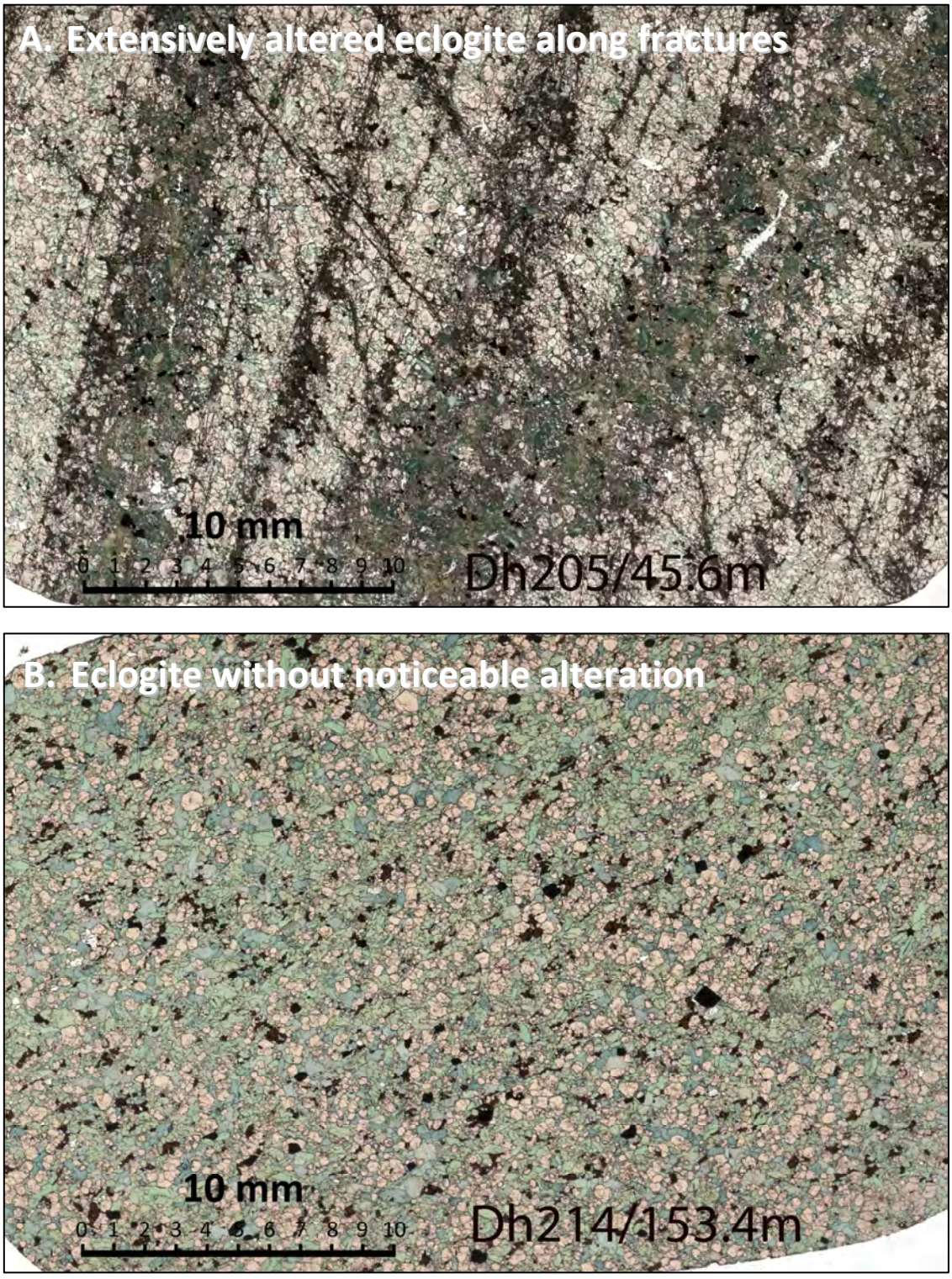


Fig. 6: Thin-section images. Fig A: Extensively altered eclogite (ore type) along the type of fractures illustrated in Fig. 3. Fig. B: Eclogite without noticeable alteration. When considering rutile-rich eclogite in general the volume-portion of insignificantly retrograded eclogite is far more common than heavily retrograded eclogite.

5. GARNET CHARACTERISTICS

Appendix 1 is an extensive visual documentation of rutile and garnet characteristics based on microphotographs and SEM-images. Quantitative information about the amount of garnet present and its grain-size distributions has been obtained by image processing of digital microphotographs, as described in Chapter 6. Area % (= volume %) garnet is determined by this procedure, and weight % garnet is calculated using an assumed specific gravity (density) 4.0 g/cm^3 for garnet and measured values for the respective sample's specific gravity, see Table 1.

GARNET GRADE (see Table 1)

- The amounts of garnet in thin-sections have been determined from a number of digital photographs covering approx. 2/3 of the thin-section, using an image processing program.
- Description of the analytical method is given in Chapter 6.
- 12 samples (thin-sections) were processed by this method; most of these are of rutile ore-type. In general, garnet grade is in the range 25-40 % by weight in rutile ore-type eclogite.
- An estimated average garnet content in rutile ore-type eclogite is 33 wt. %, based on these samples.

GARNET GRAIN-SIZE

- See Chapter 6 for detailed information.

INCLUSIONS OF OTHER MINERALS IN GARNET

- In normal rutile-ore-type eclogite garnet with the most common grain-size in the range 0.1-0.25 mm (garnet in the range 0.3-0.4 mm is fairly common) are fairly homogeneous with minor amounts of inclusions of other minerals. See for example Fig. 8a.
- In some ore-type samples inclusions in garnet are distinct, as illustrated in Fig. 8c.
- In other eclogite rock varieties that are not rutile ore and not regarded as representative of large volumes of rock, inclusions in garnet are frequent, particularly in coarse-grained garnets. See Fig. 8b.
- No precise quantitative data are available about inclusions in garnet; such information might be produced by sophisticated SEM-based image processing, if necessary.

FRACTURING OF GARNET

- In normal rutile-ore-type eclogite garnet with the most common grain-size is in the range 0.1-0.2 mm are fairly homogeneous with little or no internal fracturing, see for example Fig. 8a.
- In general, coarse-grained garnets tend to be distinctly fractured, see Fig. 8d
- No quantitative data is available on this subject.

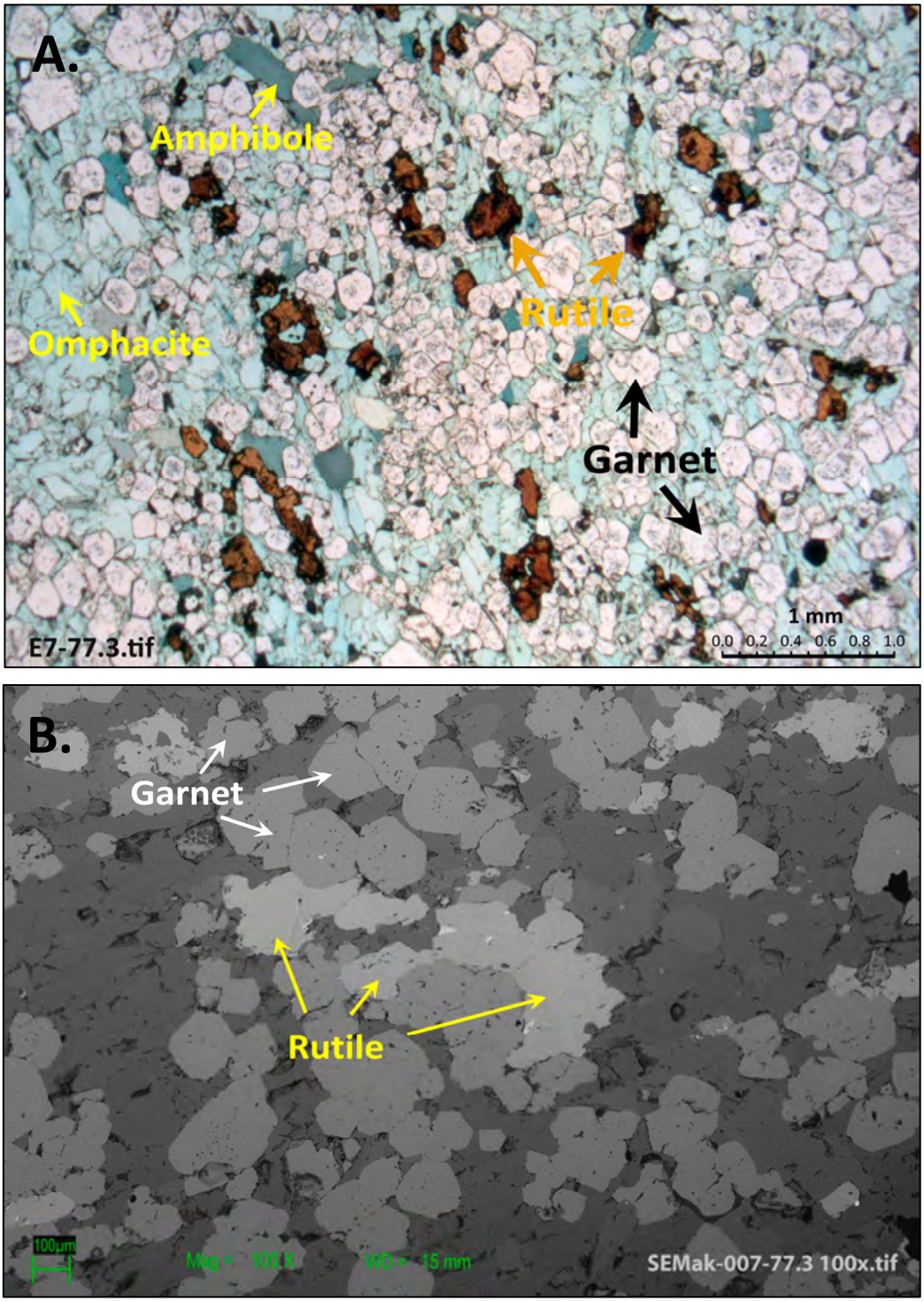


Fig. 7: Rutile- and garnet-rich eclogite. (A) Microphotograph, transmitted light; (B) SEM backscattered electron image. The garnet in this sample contains moderate amounts of inclusions of other minerals.

Table 1: Core sample information

Selected samples were taken from Engebøfjellet cores to illustrate various varieties of eclogite within the part of the deposit, in which the open pit is planned. Density and magnetic susceptibility were determined at NGU's petrophysical laboratory, while % garnet was determined based on processing of digital images of thin sections. Avg. Dcircle is the average diameter of all calculated garnet grains (see Ch. 6); the large number of small grains influences this number more than the relatively fewer large grains, giving a fairly low value.

Sample	Density (g/cm3)	Magn. susc.	vol.% Gnt	wt.% Gnt	Common Gnt grain-size	Average Dcircle	Rutile ore	Comments	For more info
205/113.5	3.53	0.00840	31.1	35.2	0.1-0.3 mm	96.3	Yes	Ferro-eclogite	Appendix1.21
205/121.7	3.52	0.00087	28.0	31.9	0.1-0.3 mm	133.3	Yes	Ferro-eclogite	Appendix1.22
205/133.5	3.60	0.00139	27.3	30.3	0.1-0.3 mm	108.5	Yes	Ferro-eclogite	Appendix1.23
205/156.4	3.60	0.00200	21.5	23.9	0.1-0.4 mm [2]	107.3	Yes	Ferro-eclogite	Appendix1.24
205/17.8	3.58	0.00622	34.2	38.2	0.1-0.2 mm	84.3	Yes?	Ferro-ecl., distinct retrogr.	Appendix1.15
205/26.6	3.39	0.00102			0.1-0.2 mm		Yes?	Ferro-eclogite	Appendix1.16
205/45.6	3.51	0.00677			0.1-0.3 mm [2]		Yes?	Ferro-ecl., distinct retrogr.	Appendix1.17
205/61.5	3.56	0.01245			0.1-0.4 mm [1, 2]		Yes?	Ferro-ecl., distinct retrogr.	Appendix1.18
205/79.4	3.55	0.00138			0.1-0.3 mm		Yes?	Ferro-ecl., distinct retrogr.	Appendix1.19
205/98.7	3.33	0.01213			0.1-0.3 mm [1, 2]		No	Heavily retrograded	Appendix1.20
214/126.9	3.07	0.03658			0.1-0.2 mm		No	Heavily retrograded	Appendix1.25
214/141.1	3.48	0.01367	19.6	22.6	0.1-0.2 mm	82.3	Yes	Ferro-ecl., distinct retrogr.	Appendix1.26
214/153.4	3.57	0.00287			0.1-0.4 mm [1, 2]		Yes	Ferro-eclogite	Appendix1.27
214/173.8	3.37	0.00105			0.1-0.2 mm		No	Leuco-eclogite	Appendix1.28
214/219.5	3.59	0.00473	31.5	35.1	0.1-0.3 mm [1]	101.4	Yes	Ferro-ecl., distinct retrogr.	Appendix1.29
7/27.7	3.56	0.00121	36.0	40.5	0.1-0.5 mm [1, 2]	101.5	Yes	Ferro-eclogite	Appendix1.01
7/34.5	3.48	0.00386	34.8	40.0	0.1-1.0+ mm [1, 2]	145.4	Yes	Ferro-ecl., distinct retrogr.	Appendix1.02
7/51.3	3.56	0.00355			0.1-0.3 mm		Yes	Ferro-eclogite	Appendix1.03
7/77.3	3.65	0.00126	40.5	44.4	0.1-0.2 mm	108.6	Yes	Ferro-eclogite	Appendix1.04
7/82.5	3.54	0.00166			0.2-1.0 mm [1, 2]		No	Leuco-eclogite	Appendix1.05
7/87.3	3.29	0.00199	34.1	41.5	0.2-2.0 mm [1, 2]	147.0	No	Leuco-eclogite	Appendix1.06
8/134.9	3.46	0.00792	31.5	36.4	0.1-0.3 mm [1, 2]	100.7	No	Low TiO2, much retrogr.	Appendix1.13
8/147.6	3.11	0.00144			0.2-1.0 mm [1, 2]		No	Low TiO2, much retrogr.	Appendix1.14
8/16.2	3.07	0.00057			0.1-0.3 mm		No	Low TiO2, much retrogr.	Appendix1.07
8/23.2	3.15	0.00063			1-3 mm [1, 2]		No	Low TiO2, much retrogr.	Appendix1.08
8/33.5	3.42	0.00087			0.1-0.2 mm		No	Low TiO2, much retrogr.	Appendix1.09
8/51.8	3.54	0.00130			0.1-0.3 mm		No	Low TiO2, much retrogr.	Appendix1.10
8/75.8	3.14	0.00495			-		No	Low TiO2, much retrogr.	Appendix1.11
8/81.2	3.41	0.00759			0.1-0.4 mm [1, 2]		No	Heavily retrogr.	Appendix1.12

[1] Much inclusions particularly in the larger garnet grains

[2] Distinct fracturing particularly of the larger garnet grains

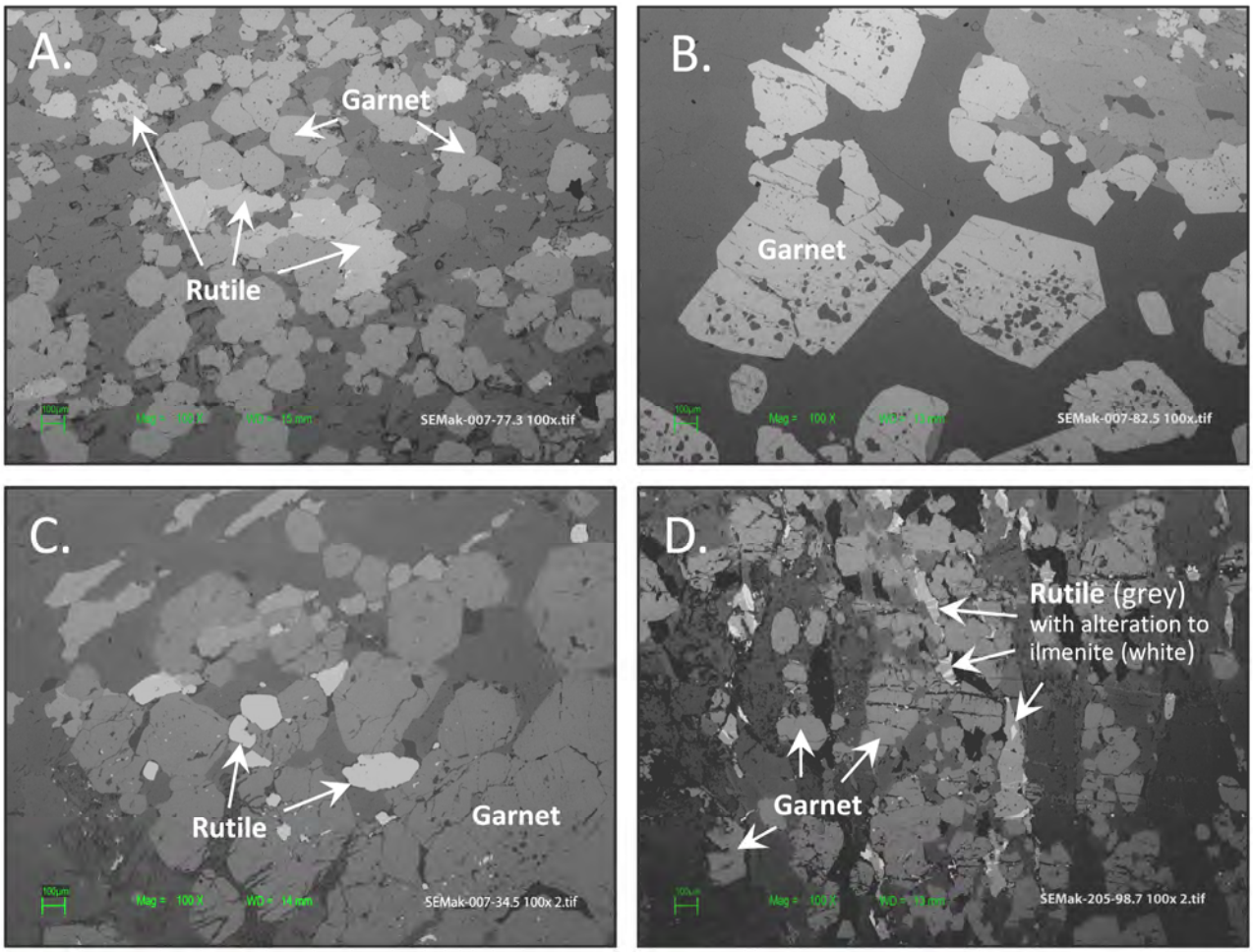


Fig. 8: SEM- images illustrating textural characteristics of garnet. (A) Fine-grained garnet without significant inclusions of other minerals, fairly representative for large volumes of eclogite rock, sample Dh7/77.3m. (B) Eclogite variety with large garnets containing numerous inclusions of other minerals; not representative for large volumes of eclogite. (C) Garnet-rich eclogite with fairly coarse-grained garnets, with moderate amounts of inclusions of other minerals; this occurrence is fairly common but probably not representative for large volumes of eclogite such as the garnet in Fig. A. (D) Distinctly altered (retrograded) eclogite in which rutile shows distinct alteration to ilmenite (white patches in rutile); garnet show signs of being fragmented and altered to amphibole (hornblende) at the margins and along cracks.

For detailed information about garnet properties and uses, see Harben (2002) as well as various articles over the years in Industrial Minerals (not further referred to in this report).

GARNET CHEMISTRY

The mineralogy of the eclogite, including description of the mineralogical characteristics of the garnet, is described by Muriel Erambert in Korneliussen et al. (1998). The data for chemical composition of the garnet, used in tables 2 and 3, are based on that report.

Table 2: Electron microprobe analyses of garnet in mafic eclogites, based on Table A5.1 in Korneliussen et al. (1998).

	Mafic eclogites (ferro-eclogite)						
Sample	E4/97.3	E4/97.3	E4/97.3	E4/130.3	E4/130.3	E3/159.8	E3/159.8
	core	core	rim	core	rim	core	rim
SiO_2	38.14	38.33	38.38	37.57	38.10	38.46	38.75
TiO_2	0.19	0.07	0.03	0.09	0.06	0.22	0.00
Al_2O_3	20.62	20.94	21.27	20.66	20.63	20.92	21.34
Cr_2O_3	0.01	0.00	0.03	0.00	0.00	0.00	0.01
FeO_t	26.88	27.29	28.84	30.35	31.27	26.92	27.80
MnO	0.53	0.79	0.52	1.84	0.91	0.69	0.51
MgO	3.78	3.50	4.08	2.32	3.36	3.91	4.99
CaO	9.73	9.49	8.00	7.68	6.43	9.64	7.66
Na_2O	0.05	0.02	0.00	0.04	0.02	0.06	0.00
K_2O	0.00	0.03	0.00	0.00	0.01	0.01	0.01
NiO	0.03	0.04	0.00	0.00	0.00	0.01	0.01
Sum	99.96	100.50	101.14	100.55	100.78	100.83	101.08
Structural formulae (based on 24 oxygens and 16 cations)							
Si	6.00	6.01	5.98	5.97	6.02	5.99	6.00
Ti	0.02	0.01	0.00	0.01	0.01	0.03	0.00
Al	3.82	3.87	3.90	3.87	3.84	3.84	3.90
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe^{3+}	0.15	0.09	0.13	0.18	0.12	0.14	0.10
Fe^{2+}	3.39	3.49	3.63	3.86	4.01	3.36	3.51
Mn	0.07	0.10	0.07	0.25	0.12	0.09	0.07
Mg	0.89	0.82	0.95	0.55	0.79	0.91	1.15
Ca	1.64	1.59	1.34	1.31	1.09	1.61	1.27
Na	0.02	0.00	0.00	0.01	0.00	0.02	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Garnet end-members							
Alm	56.58	58.10	60.70	64.68	66.66	56.33	58.46
Spe	1.18	1.74	1.14	4.14	2.04	1.52	1.12
Pyr	14.81	13.62	15.83	9.23	13.18	15.20	19.21
Gro	23.65	24.31	19.18	17.46	15.09	23.35	18.82
And	3.77	2.23	3.15	4.49	3.02	3.60	2.40

Table 3: Electron microprobe analyses of garnet in mafic to intermediate, layered and leuco-eclogites, based on Table A5.1 in Korneliussen et al. (1998).

	Mafic to intermediate eclogites					Layered eclogite		Leuco-eclogite		
Sample	E1/101.9	E1/101.9	E1/101.9	E8/229.0	E8/229.0	E1/164.2	E1/164.2	E3/33.9	E3/33.9	E3/33.9
	core	core	rim	core	rim	rim	rim	core	rim	rim
SiO_2	38.34	38.55	37.80	37.54	37.79	37.89	38.18	38.97	38.87	38.78
TiO_2	0.15	0.05	0.02	0.10	0.06	0.08	0.05	0.06	0.05	0.00
Al_2O_3	20.76	21.01	20.60	20.36	20.57	20.45	21.28	21.46	21.58	21.46
Cr_2O_3	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.05	0.08	0.09
FeO_t	28.43	28.15	29.41	30.44	30.82	30.59	29.15	24.54	25.13	25.07
MnO	0.55	0.95	0.53	1.02	0.47	1.02	0.28	0.80	0.54	0.57
MgO	3.09	2.97	3.24	2.39	2.19	2.94	4.34	6.13	6.17	5.72
CaO	10.01	10.04	8.16	8.51	8.74	7.67	7.55	8.37	7.89	8.31
Na_2O	0.06	0.03	0.04	0.07	0.01	0.04	0.04	0.04	0.02	0.02
K_2O	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00
NiO	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.05
Sum	101.38	101.76	99.85	100.46	100.69	100.68	100.89	100.44	100.38	100.06
Structural formula (on 24 oxygens and 16 cations)										
Si	5.98	5.99	6.00	5.96	5.99	5.99	5.96	6.01	6.00	6.02
Ti	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Al	3.82	3.85	3.85	3.81	3.84	3.81	3.91	3.90	3.93	3.93
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Fe^{3+}	0.21	0.17	0.16	0.26	0.16	0.20	0.18	0.08	0.04	0.02
Fe^{2+}	3.50	3.49	3.74	3.78	3.93	3.84	3.63	3.09	3.21	3.24
Mn	0.07	0.12	0.07	0.14	0.06	0.14	0.04	0.10	0.07	0.07
Mg	0.72	0.69	0.77	0.57	0.52	0.69	1.01	1.41	1.42	1.32
Ca	1.67	1.67	1.39	1.45	1.48	1.30	1.26	1.38	1.31	1.38
Na	0.02	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ni	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Garnet end-members										
Alm	58.67	58.43	62.72	63.73	65.54	64.34	61.12	51.59	53.40	53.80
Spe	1.22	2.08	1.19	2.30	1.06	2.30	0.62	1.75	1.18	1.23
Pyr	12.05	11.52	12.86	9.54	8.63	11.61	16.98	23.56	23.66	22.01
Gro	22.78	23.81	19.23	17.76	20.82	16.71	16.84	21.15	20.76	22.57
And	5.27	4.16	4.01	6.67	3.95	5.04	4.43	1.95	0.99	0.39

6. QUANTIFICATION OF GARNET BY OPTICAL MICROSCOPY AND IMAGE PROCESSING

Materials and methods

Garnet can be quantified based on digital optical microscopy of thin sections, as long as colors are uniform and different from other minerals in the same picture. The method requires that the microscope and images are size calibrated, i.e. the exact size in μm^2 of each pixel must be known. For Engebøfjell eclogite using partly crossed polarizers it is possible to get pictures in which garnet has a distinct, uniform color.

We use the program KS300 from Carl Zeiss and the method consists of the following steps:

(a) An initial microphotograph is taken with low magnification to cover as large a part of the thin-section as possible (Fig. 9), at the expense of resolution.

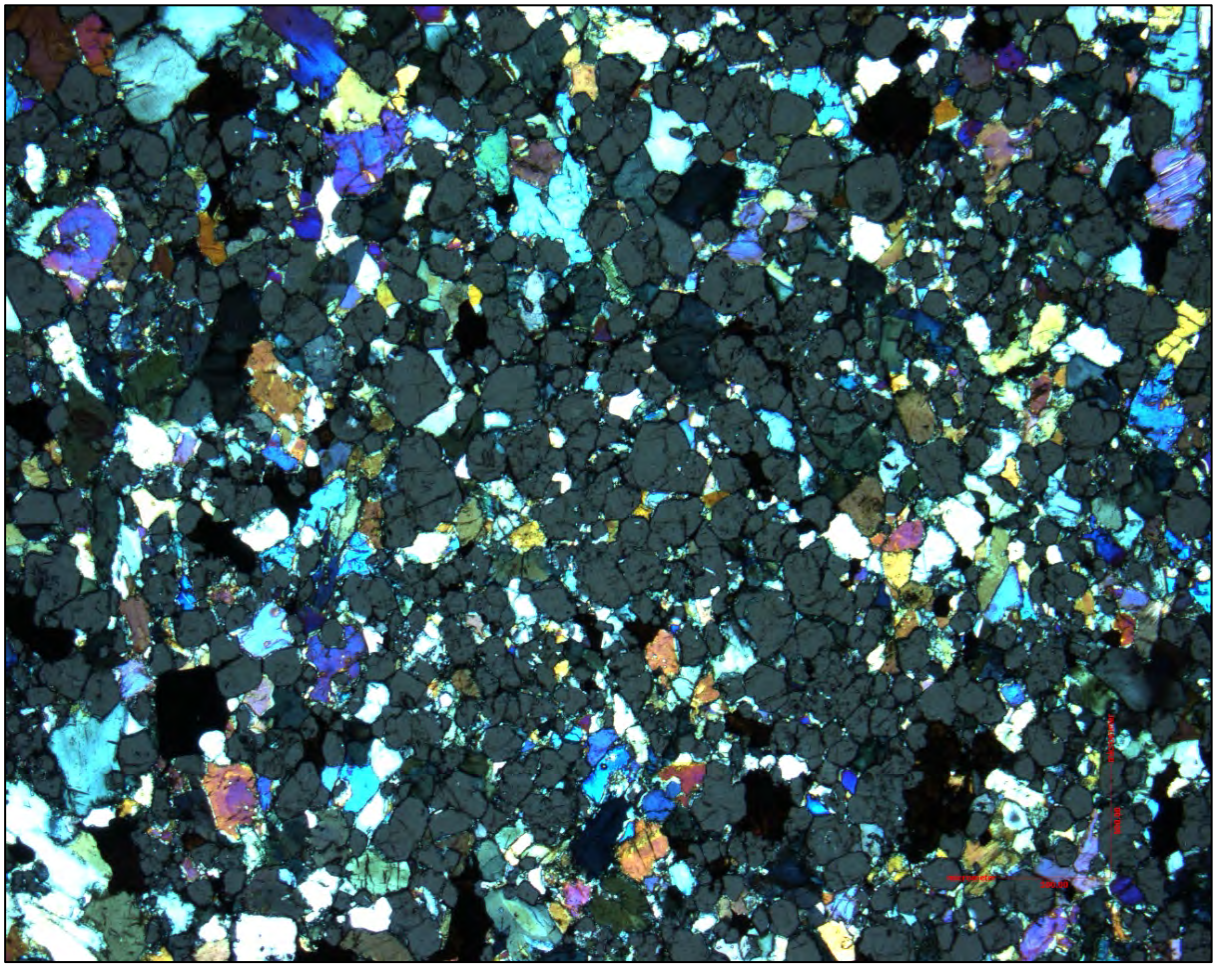


Fig. 9: Microphotograph of thin section (DH205/113.5) in partly polarized light, with a scale bar of 500 micrometers. Minerals in uniform grey color are garnet. In this type of image there is a distinct dark/black rim effect around the garnet grains which in the processing is calculated as not-garnet. The error caused by this interpretation is unknown.

(b) Picture from (a) is segmented to give a binary image (black and white only), were white areas are the garnet grains (Fig 10). This temporary image contains noise and artifacts that must be removed before calculations.

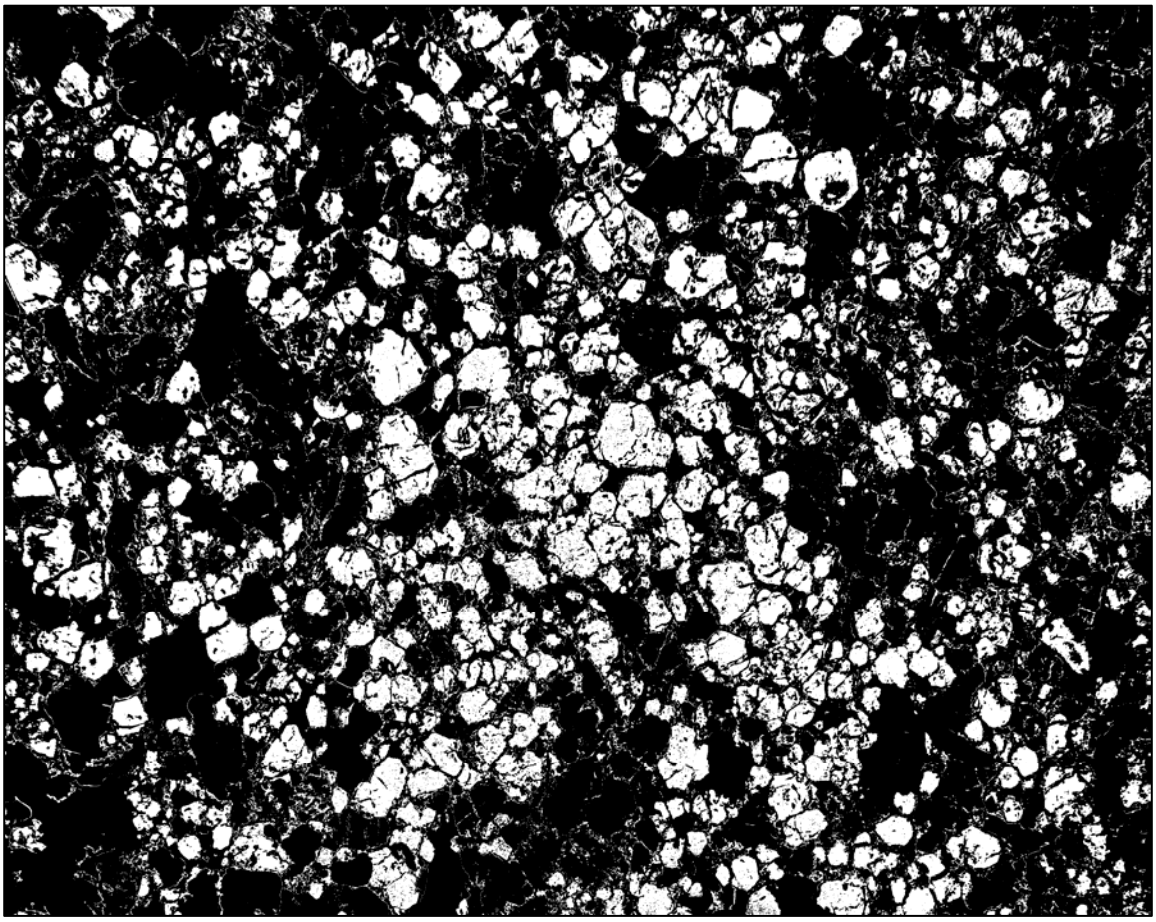


Fig. 10: Temporary binary image after segmentation of Fig. 9. See text for explanation.

(c) During a series of manual and automated steps involving binary erosion, dilation and closure. Noise and small unwanted white areas are removed from Fig. 9. This result in a final binary image is (Fig. 11) where the white areas represent the garnet crystals with a good approximation. The software make it possible to compare the final and initial images, and stop the binary processing when satisfactory results are achieved (Fig. 11 and 12).

The percentage (area %, equal to volume % for homogeneous rocks without oriented elongated minerals) of white area represents the percentage of garnet in this case. When the microscope is size calibrated so that the size of a pixel is known then the size (= area, equal to volume) and a series of other parameters for each individual grain can be calculated and the corresponding numerical values stored in a spreadsheet.

(d) The steps (a) to (c) are repeated several times to cover different areas of the thin section so that a large portion of the thin-section is covered altogether, and average results are calculated. This procedure takes approximately 15 minutes per thins-section.

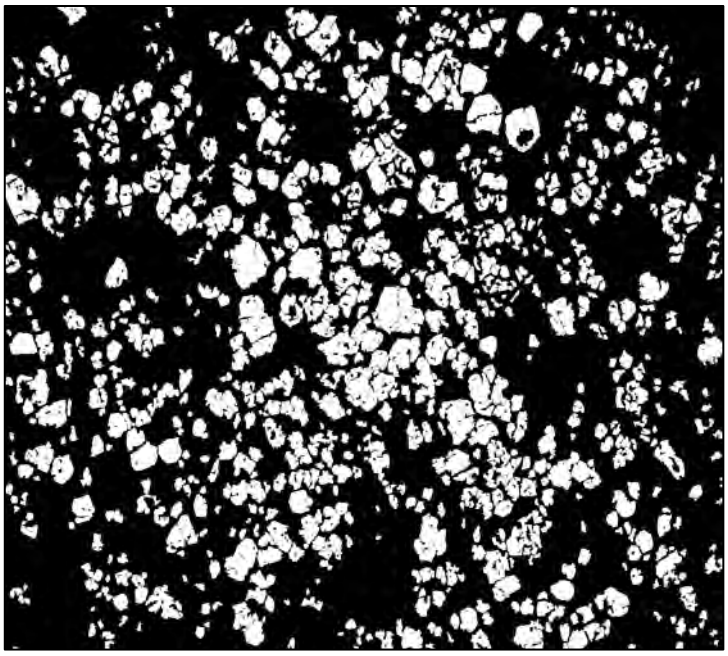


Fig. 11: Processed binary image, where white areas represent garnet in Fig. 9. White areas are calculated and the numerical values are saved in tables like Table 6

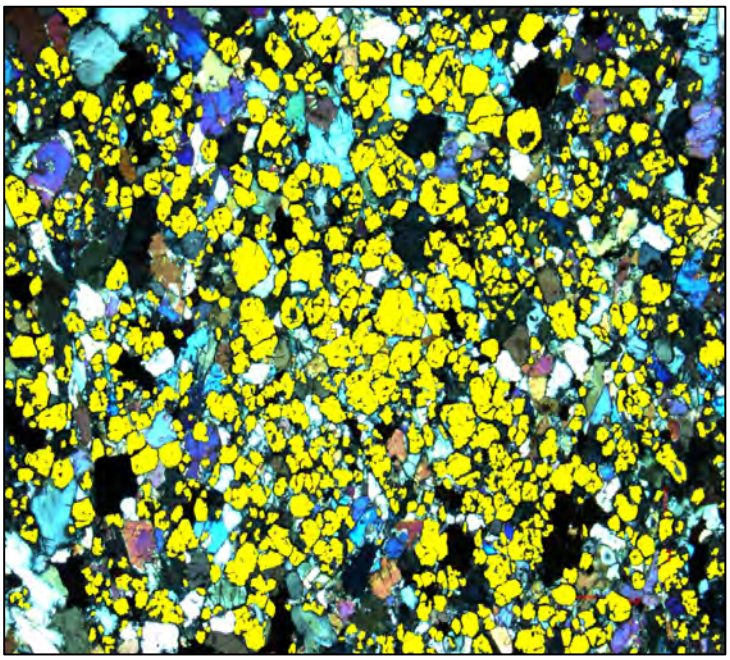


Fig. 12: White areas in Fig. 11 are colored yellow and superimposed on Fig. 9. The result is a picture where garnet has a yellow color,

Based on Fig. 11 the total area (= volume) percentage of garnet is calculated (in Fig.12 area % garnet is 31.39%).

In this procedure numbers are obtained for the following parameters for each individual garnet grain (see Table 6):

- AREA: The area of each particle in μm^2

- AREAF: The filled area of particle μm^2, the difference between AREA and AREAF gives an indication of the amount of inclusions in the garnet.
- ELLIPSEA and ELLIPSEB: The longest and shortest axis of a calculated ellipse surrounding each grain.
- FERETMAX and FERETMIN: Shortest and longest axis of grain
- DCIRCLE: DCIRCLE is defined as the diameter in a circle with area equal to the area of the measured grain and is given by

  $$DCIRCLE = 2\left(\sqrt{\frac{AREAF\ of\ particle}{\pi}}\right)$$

  DCIRCLE calculates the diameter in each grain as if they are perfect circles, this makes it possible to compare the size of each grain and calculate the grain size distribution.
- FCIRCLE is a parameter that indicates that shape of each grain. A perfect circle will have FCIRCLE = 1 and the more the shape deviates from a circle the lower the value.
- Area2 is the relative portion of each garnet grain vs. the sum of all grains.
- CumArea2 is the cumulate sum of Area2.
- CA2perc is the cumulate percentage based on CumArea2. The cumulate garnet (Y-axis) of Fig. 13 is based on this data column in combination with grain size defined by DCIRCLE (X-axis).

Limitations of the method and sources of error

This method of quantification of garnet in the eclogite has the advantage of being quick and therefore cheap, and requires only an optical microscope with digital image-saving options and specialized image processing software.

However the method has limitations and sources of error, such as:

1. Grains in contact with each other will be calculated as one big grain. It is believed that a large portion of large grains (400-500 microns and more) are of this category.
2. Minerals other than garnet with the same color as garnet will be calculated as garnet. However, the error caused by this effect is believed to be minor except in heavily retrograded eclogite where overlapping characteristics between garnet and other minerals (mainly amphibole) prevented generation of reliable data.
3. The present set-up at NGU cannot handle small details; the software for processing the binary images is not able to handle (measure) sizes under 20 to about 50 microns. This can later on be improved by generating high-resolution mosaic images, although this option is not presently available.

It is also important to emphasize that the size distributions that are calculated are those measured from thin sections. This will be different from the size distribution of garnet in a crushed sample.

This method of garnet quantification can be significantly improved by increasing the resolution of the digital microphotographs used as basis for the image processing, by automatically generating a large high-resolution image based on many individual photos taken in mosaic and stitched together. Then it would probably also be possible to obtain good data on inclusions in garnet.

Another way of generating such information is by SEM back-scattered images. However, also in this case, a high-resolution mosaic image based on many individual images stitched together is required to obtain high-quality data.

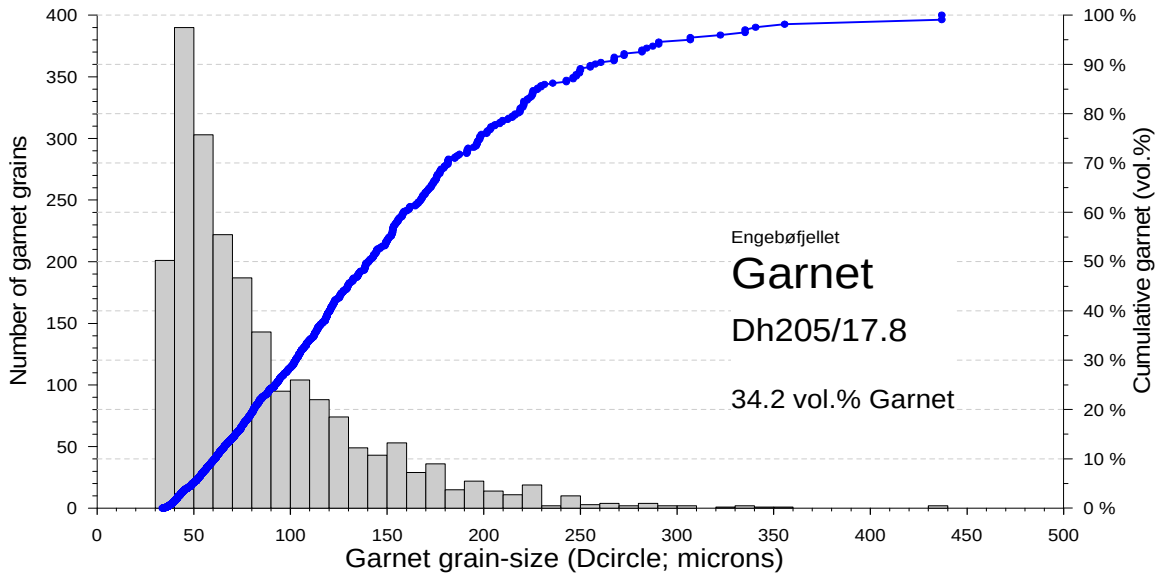


Fig. 13: Illustration of garnet grain-size information obtained by the method described in the text. The histogram show numbers of garnet grains vs. grain size intervals while the line diagram show cumulative percent garnet content.

Table 4: Example of data table generated by the image processing procedure described in the text. This table shows the beginning and end of a table that has 2134 data rows altogether; sample Dh205/17.8.

Line	No	AREA	AREAF	ELLIPSEA	ELLIPSEB	FERETMAX	FERETMIN	DCIRCLE	FCIRCLE	Area2	CumArea2	CA2perc
1	591	892.42	892.42	18.93	15.36	39.98	33.14	33.71	0.89	0.00006	0.00006	0.00558
2	1150	917.79	917.79	22.12	13.60	46.13	28.69	34.18	0.83	0.00006	0.00011	0.01133
3	1310	917.79	917.79	19.04	15.71	41.46	34.76	34.18	0.81	0.00006	0.00017	0.01707
4	1844	917.79	917.79	22.12	13.60	46.13	28.69	34.18	0.83	0.00006	0.00023	0.02281
5	2004	917.79	917.79	19.04	15.71	41.46	34.76	34.18	0.81	0.00006	0.00029	0.02855
6	1191	922.02	922.02	18.28	16.44	40.45	33.02	34.26	0.86	0.00006	0.00034	0.03432
7	1885	922.02	922.02	18.28	16.44	40.45	33.02	34.26	0.86	0.00006	0.00040	0.04009
Lines 8-2127												
2128	340	79839.64	81637.16	276.72	126.14	623.10	309.25	322.40	0.09	0.00500	0.95955	95.95527
2129	1359	83937.99	88239.36	253.22	129.27	588.50	360.27	335.19	0.14	0.00525	0.96480	96.48042
2130	2053	83937.99	88239.36	253.22	129.27	588.50	360.27	335.19	0.14	0.00525	0.97006	97.00556
2131	282	85240.67	91136.54	229.55	141.46	533.84	371.11	340.64	0.09	0.00533	0.97539	97.53885
2132	192	98339.33	99345.94	302.60	141.10	704.74	361.80	355.66	0.07	0.00615	0.98154	98.15409
2133	988	147523.79	149921.90	272.70	206.64	628.60	493.94	436.91	0.08	0.00923	0.99077	99.07705
2134	1682	147523.79	149921.90	272.70	206.64	628.60	493.94	436.91	0.08	0.00923	1.00000	100.00000

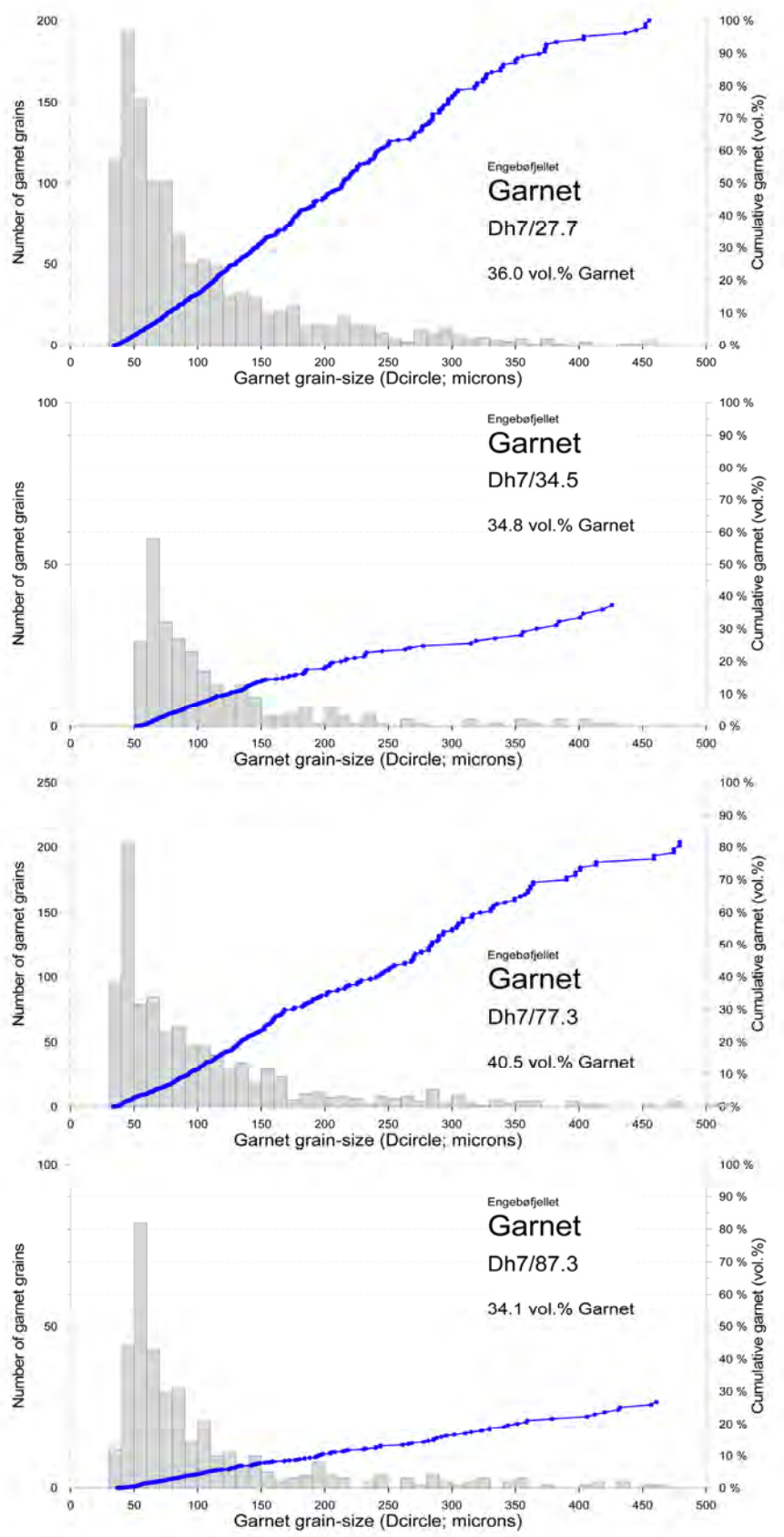
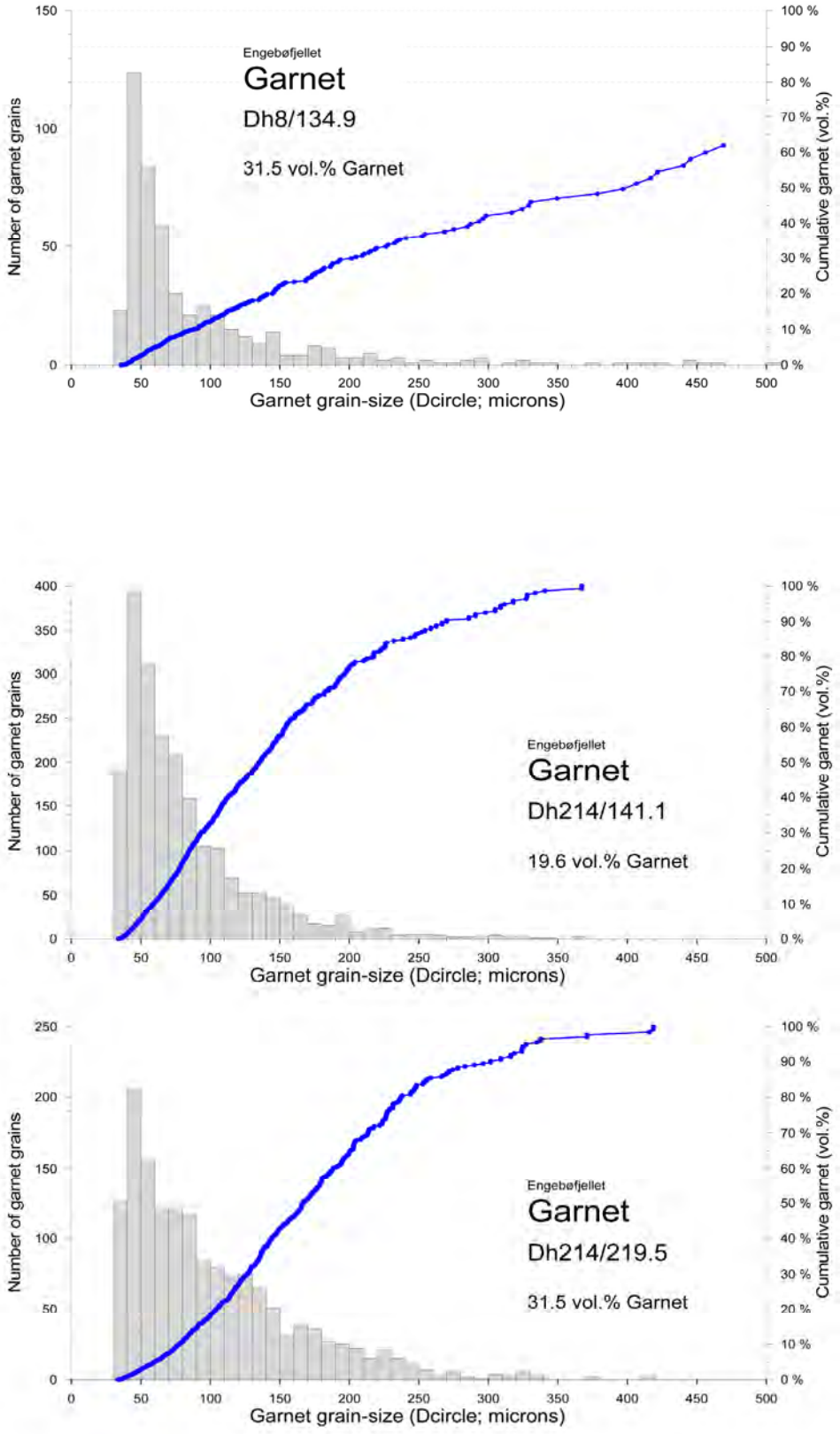


Fig. 14: Garnet grain-size distribution for samples (thin sections) from borehole 7.

Garnet grain-size characteristics vary considerably between these samples, as indicated particularly by the four line-diagrams. When roughly compared: In sample Dh7/27.7 approx. 50 vol. % of the garnet is less than 220 microns, in sample Dh7/34.5 a large portion of the garnets are outside the range of the diagram, i.e. the 50 vol. % boundary is above 500 microns; in sample Dh7/77.3 50 vol. % of the garnet is less than 290 microns; and in sample Dh7/87.3 the 50 vol. % boundary is above 500 microns.

See the main text for further explanation of method.

NB! The garnet 50 vol. % boundary obtained by this method is too high due to the effect of "large grains" representing smaller grains in direct contact with each other.



NB! The garnet 50 vol. % boundary obtained by this method is too high due to the effect of "large grains" representing smaller grains in direct contact with each other.

Fig. 15: Garnet grain-size distribution for samples (thin sections) from boreholes 8 and 214. See explanation in the main text about the method. The garnet grain-size distribution patterns are distinctly different between sample Dh8/134.9 and the two Dh215 samples. In sample Dh8/134.9 approx. 50 vol. % of the garnet is less than 400 microns, while in sample Dh214/141.1 and Dh214/219.5 50 vol. % of the garnet is less than 140 and 160 microns, respectively.

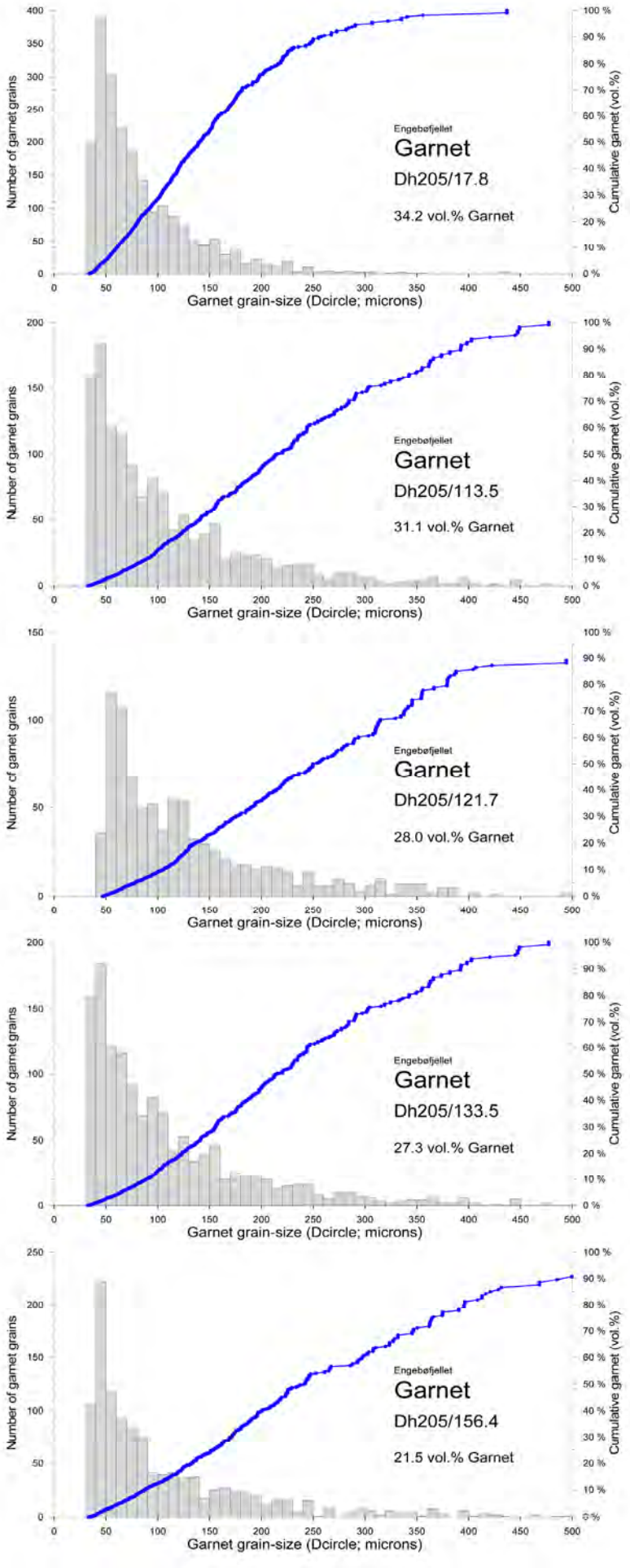


Fig. 16: Garnet grain-size distribution for five samples (thin sections) from borehole 205. See explanation in the main text about the method.

Roughly, the 50 vol. % garnet grain-size boundary is as follows for these five samples:

- 90 microns (Dh205/17.8)
- 220 microns (Dh205/113.5)
- 250 microns (Dh205/121.7)
- 210 microns (Dh205/133.5)
- 240 microns (Dh205/156.4)

NB! The garnet 50 vol. % boundary obtained by this method is too high due to the effect of "large grains" representing smaller grains in direct contact with each other.

7. DISCUSSION

There is little doubt that Engebøfjellet garnet represents a major mineral resource of large potential value if garnet concentrates of sufficient quality for various applications can be made.

The documentation provided in this report is probably sufficient at the present stage to document that “enough” garnet is present, while important garnet parameters such as grain-size distribution and the amount and character of inclusions of other minerals may not yet be sufficiently documented.

Depending on how the continued processing trials to produce garnet concentrates develop, it might, at a later stage, be relevant to carry out more extensive studies (optical and SEM-based) of garnet grain-size and to quantify inclusions of other minerals in garnet such as quartz, and how these vary between the different parts of the deposit.

At the present stage mineral processing is crucial, to show that garnet concentrates of sufficiently high quality can actually be produced.

The data presented in this report is semi-quantitative due to the low resolution of the microphotographs used as a basis for image processing; this technique can be highly improved (but is not yet available at NGU) by implementing an automated technique of generation high-resolution images based on microphotographs taken in a mosaic pattern and stitched together, to cover sufficiently large parts of each thin section. Even better results might be obtained by implementing an automated mosaic back-scattered electron images by SEM, to be processed in a similar way.

The quantitative data on garnet provided in this report illustrate clearly that there is a significant variation in garnet grain-size characteristics within the deposit.

Altogether, the quantitative data combined with the microphotographs and SEM-images in Appendix 1 are a fairly extensive characterisation of garnet in the Engebøfjellet eclogite, and represent a good basis for evaluating the garnet potential of the eclogite.

Large garnet grains (usually approx. 400 microns or larger) tend to contain significant amounts of inclusions of other minerals, they also tend to occur in eclogite that is not of rutile ore quality; it is therefore probably not relevant to consider such garnets for garnet production.

Significant portion of the larger garnet grains registered by the image processing method are combined grains in which neighbouring smaller garnets are in direct contact with each other, and are interpreted in the image processing to be large grains. In a garnet production situation such grains would behave like the individual smaller grains.

In crushing and milling garnets would probably tend to break up along micro fractures. Visual documentation of micro fractures in garnet is provided by microphotographs in Appendix 1, but no quantitative information about this phenomenon exists. The larger garnets in particular, tend to contain such fractures, and would probably easily break up into smaller pieces in a production situation. The importance of this factor in relation to the production of coarse-grained garnet concentrates should not be underestimated.

Based on this information it should, in theory, be possible to produce garnet concentrates from Engebøfjellet eclogite spanning 100 to 300 microns in grain-size. A key issue is to show that this can be done in reality; mineral processing is crucial.

The terms leuco-eclogite, transitional eclogite, ferro-eclogite and mafic eclogite might be confusing; the background for these terms is a follows: At an early stage in the DuPont-project (1995-97) it became clear that there is a positive correlation between titanium and iron in the rock. It also turns out that iron-rich eclogite is usually also garnet-rich, since much of the iron in the rock enters garnet,

the most iron-rich of the major minerals in eclogite. Consequently, garnet-rich eclogites are usually also titanium-rich.

The term "ferro-eclogite" was invented to distinguish ore-type eclogite with high garnet content and more than 3 % TiO_2; the titanium content (and iron) was quantified in the field by analyses directly on the rock surface and on cores by portable XRF (Outokumpu X-Met), while there were no precise way to quantify garnet in the field. The ferro-eclogite is a dark reddish (due to garnet) fine-grained rock; "mafic eclogite" is another term used for the same rock.

In general "leuco-eclogite" is a less dark eclogite with lower iron and titanium contents (less than 3 % TiO_2), and the term "leuco-eclogite" was invented to help in distinguishing between rutile ore (ferro-eclogite) from eclogites that are not of rutile ore quality. In practice this distinction was problematic due to gradual transitions, and the term "transitional eclogite" was invented.

The term "gneiss" was used for gneissic felsic-mafic country-rocks as well as for dyke-like zones or bands in ferro-eclogite, usually a few dm thick, consisting of gneissic mica- and quartz-rich leuco-eclogite.

8. CONCLUSION

This report provides documentation of eclogite and garnet characteristics including quantitative data on garnet chemical composition, amounts of garnet present and grain-size distributions.

Based on image processing of 12 thin-sections of rutile ore-type eclogite, the garnet content generally varies from 25 to 40 wt. %, with an average of 33 wt. % garnet.

The garnet is fairly iron-rich with a high almandine component, average FeO_t, CaO and MgO contents are 28.3, 8.5 and 3.8 wt. %, respectively. Average garnet end-members are Alm 59.8, Spe 1.6, Pyr 14.9, Gro 20.3 and And 3.5.

Inclusions of other minerals in garnet are common, particularly in the larger garnet grains. Both garnet grain-size and amount of inclusions vary considerably from sample to sample. However, although inclusions are common, the amount of inclusions in representative 100-250 micron garnets in rutile ore-type eclogite is regarded as low.

Particularly the larger garnets tend to contain micro fractures and would probably easily break up into smaller pieces in a production situation, but no quantitative information about this phenomenon exists.

In representative rutile-ore-type eclogite the garnet grain-size is commonly in the range 100 to 250 microns (0.1-0.25 mm); larger garnet grains in the range 250-400 microns seem to occur fairly frequently. It is probable but not proven, that the main limitations in utilising the larger garnets would be the distinct internal fracturing and the increased amount of inclusions. Based on this information it is believed that high-quality garnet concentrates with garnet grain-size in the range 100 to 250 microns might be produced from Engebøfjellet eclogite, while it is unlikely that the larger garnets can be utilised.

Continued mineral processing experiments are crucial, and these should be carried out hand-in-hand with relevant optical and SEM-based characterisation of garnet fractions from the experiments. To have good mineralogical control is essential.

9. REFERENCES

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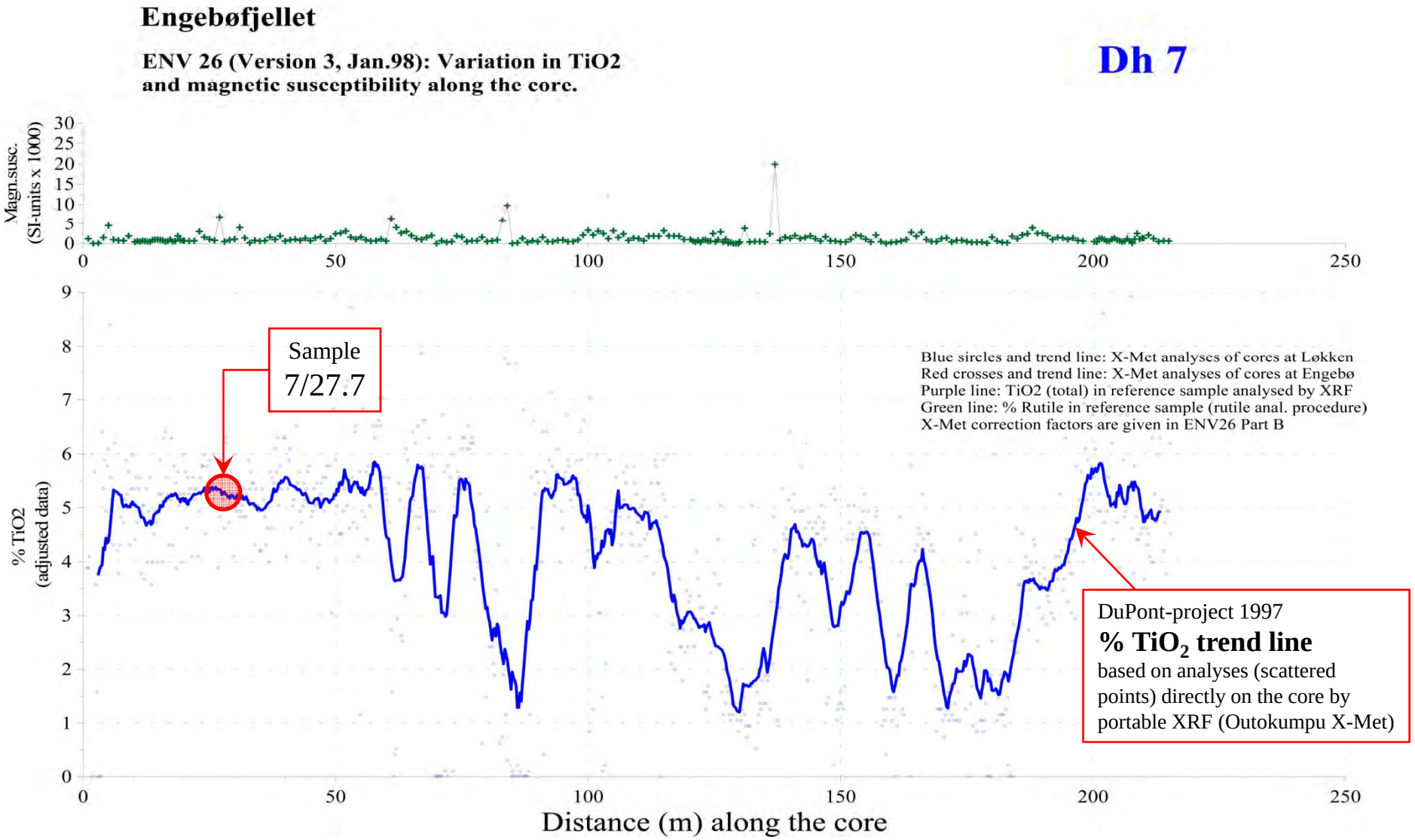
Korneliussen, A., McLimans, R., Braathen, A., Erambert, M., Lutro, O. & Ragnhildstveit, J. 2000: Rutile in eclogites as a mineral resource in the Sunnfjord region, western Norway. Norges geologiske undersøkelse Bulletin 436, 39-47.

Korneliussen, A., Wanvik, J.E. and M.A.T.M. Broekmans 2007: Engebøfjellet: prospect of a major rutile deposit. NGU report 2007.055, 19 p.

Korneliussen, A. & Raaness, A. 2005: Engebøfjellet rutile deposit. Web-presentation available at http://www.ngu.no/mineralforekomster/engebofjellet/index.php

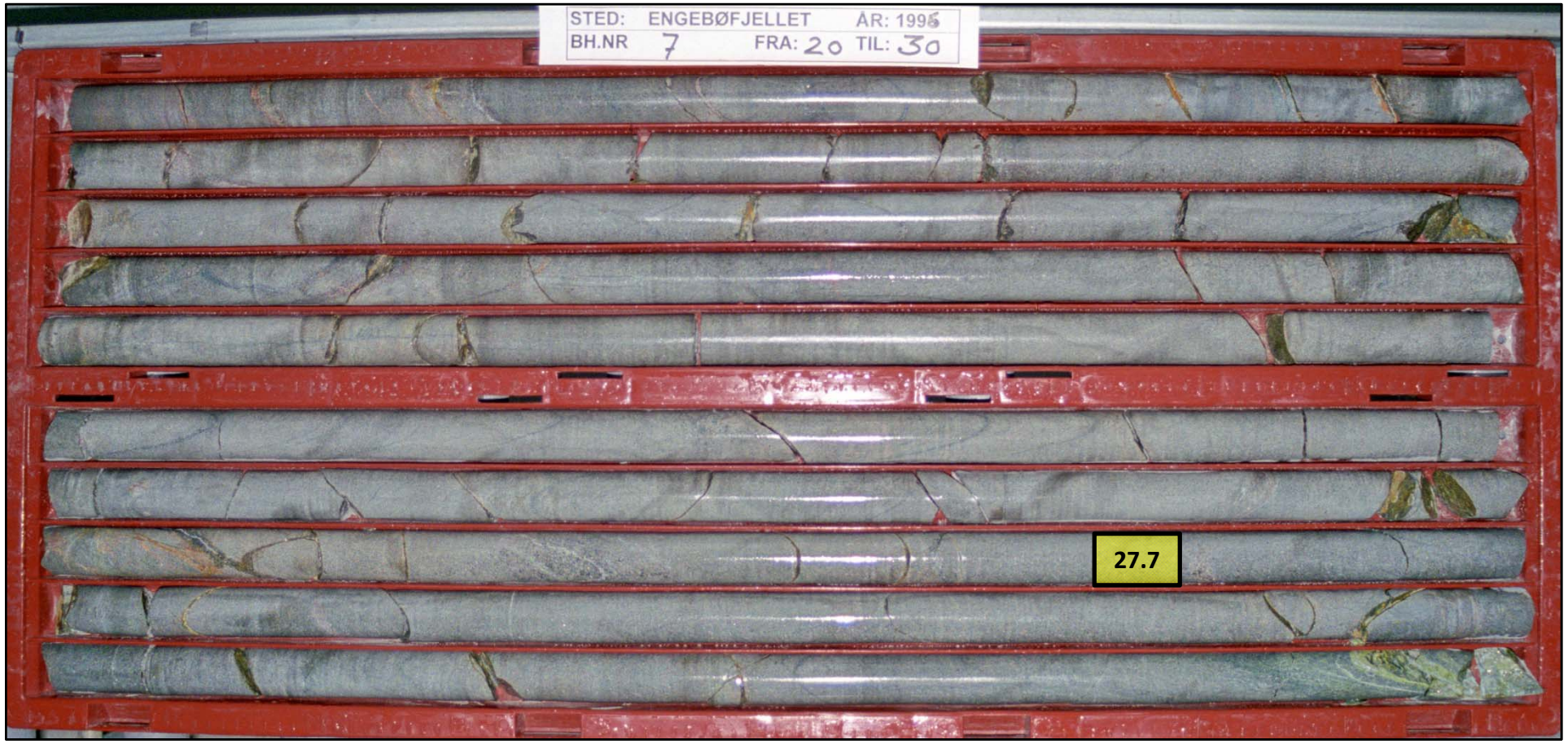
Engebøfjellet core sample information

Sample Dh7/27.7m



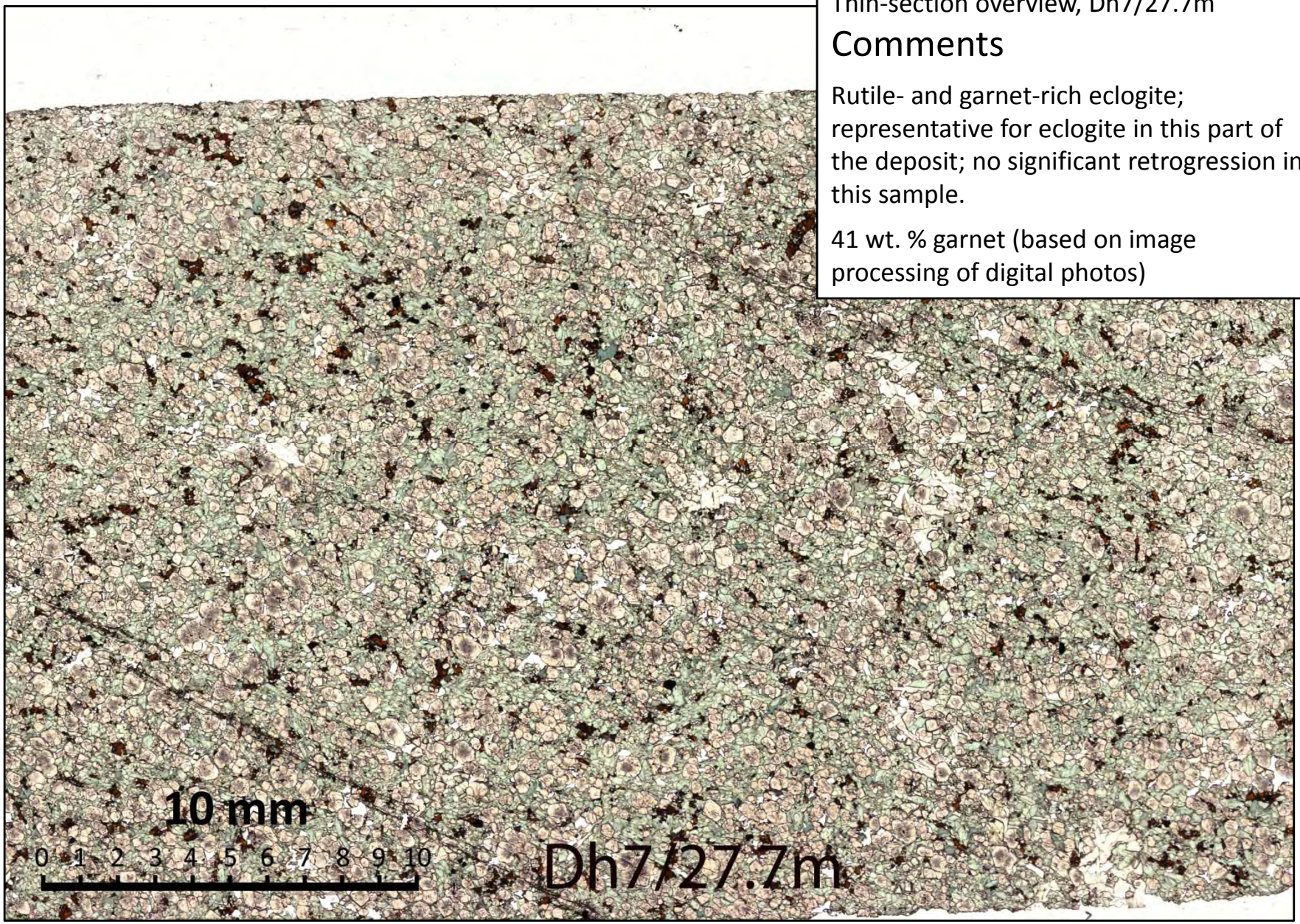
Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; probably fairly representative for a significant volume of eclogite in this part of the deposit; locally retrograded along fractures and more diffusely infiltrated into the rock, but retrogression is probably not seriously affecting the overall character of the rock.



Sample description

- Massive eclogite; believed to be fairly representative for this part of the deposit.
- Magnetic susceptibility: 0.00121 (SI-units)
- Specific gravity: 3.56 g/cm^3
- 2.4 % TiO_2 , 17.5 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)



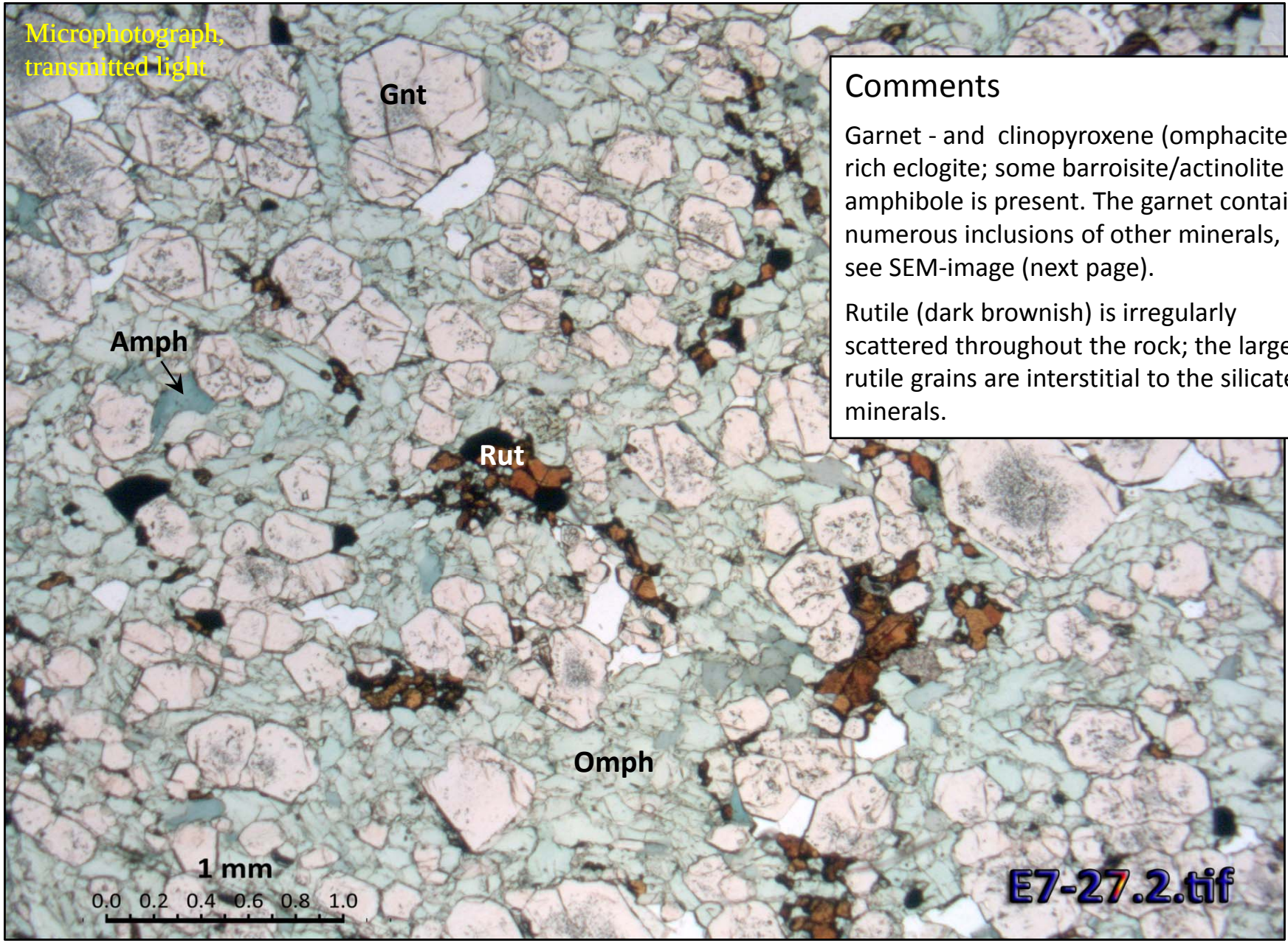
Thin-section overview, Dh7/27.7m

Comments

Rutile- and garnet-rich eclogite; representative for eclogite in this part of the deposit; no significant retrogression in this sample.

41 wt. % garnet (based on image processing of digital photos)

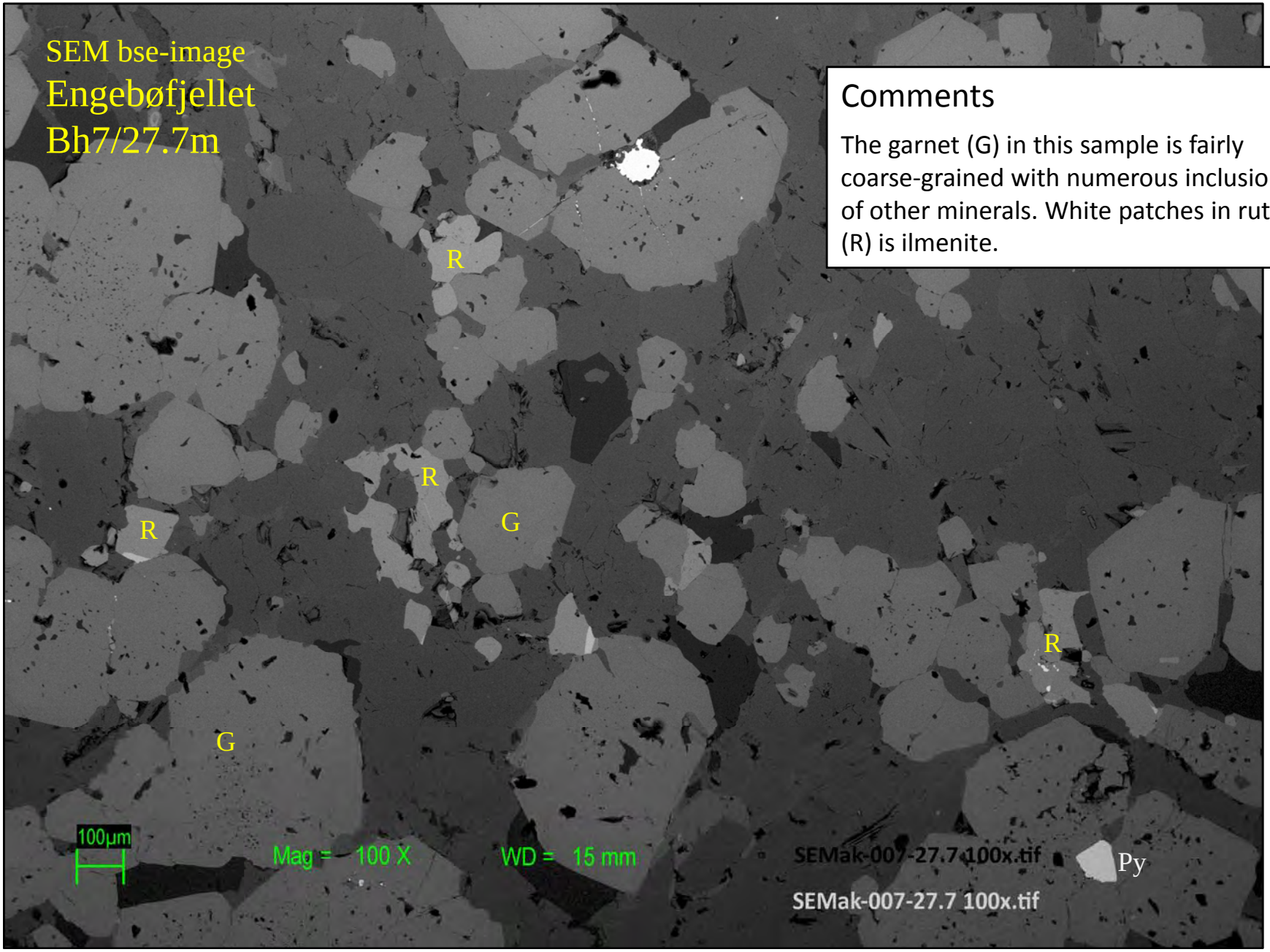
Engebøfjellet, Bh7/27.7m



Comments

Garnet - and clinopyroxene (omphacite) rich eclogite; some barroisite/actinolite amphibole is present. The garnet contains numerous inclusions of other minerals, see SEM-image (next page).

Rutile (dark brownish) is irregularly scattered throughout the rock; the larger rutile grains are interstitial to the silicate minerals.

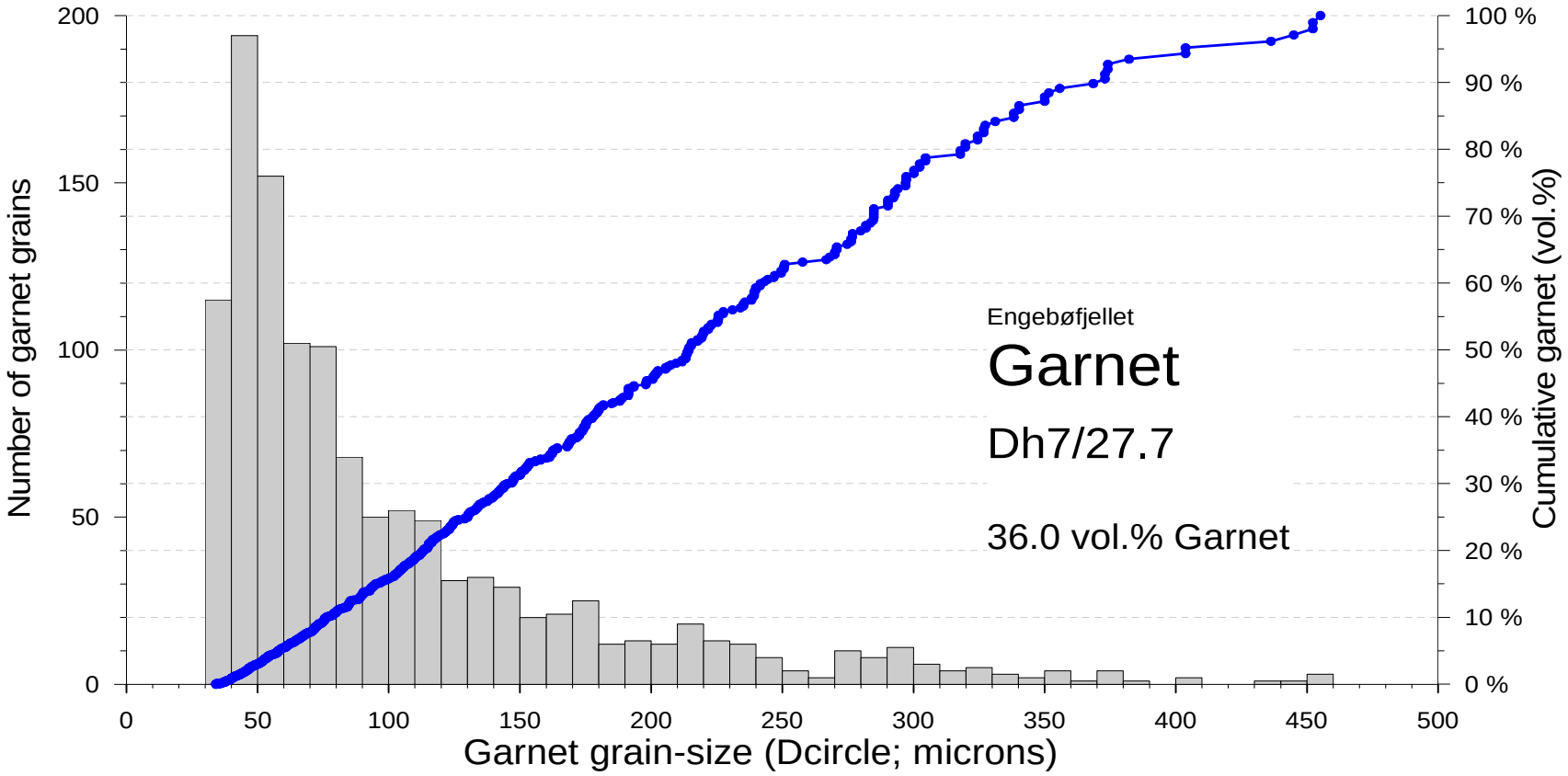


Comments

The garnet (G) in this sample is fairly coarse-grained with numerous inclusions of other minerals. White patches in rutile (R) is ilmenite.

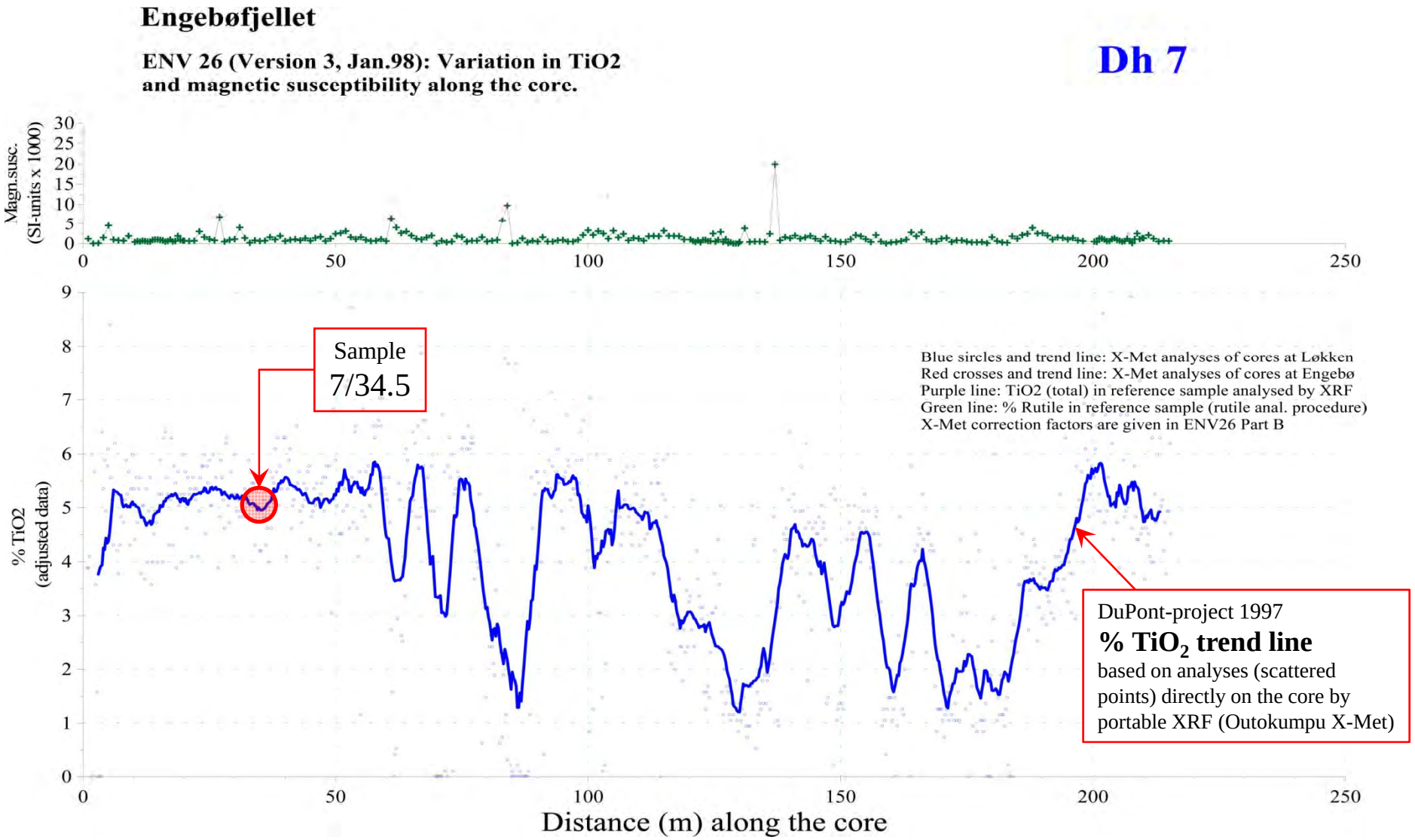
Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet present is less than 210 microns. However, since grains attached to each other is registered as one larger grain by this method, the real garnet 50 vol. % boundary is probably below 210 microns.



Engebøfjellet core sample information

Sample Dh7/34.5m



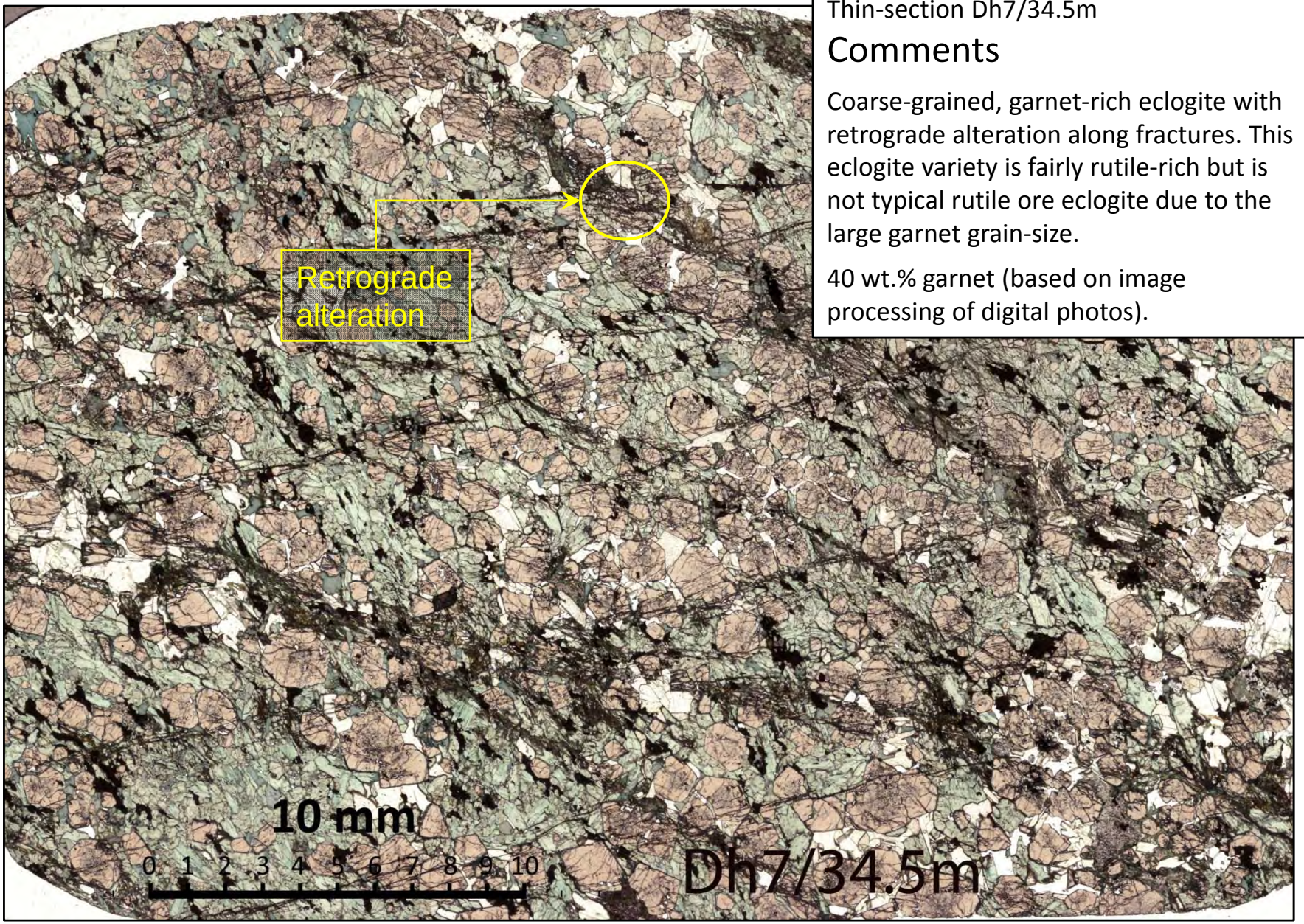
Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 19979.
- Coarse-grained eclogite.

Engebøfjellet, Bh7/34.5m

Key information

- Eclogite; fairly coarse-grained garnets
- Magnetic susceptibility: 0.00386 (SI-units)
- Specific gravity: 3.48 g/cm^3
- 2.6 % TiO_2 , 16.5 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)



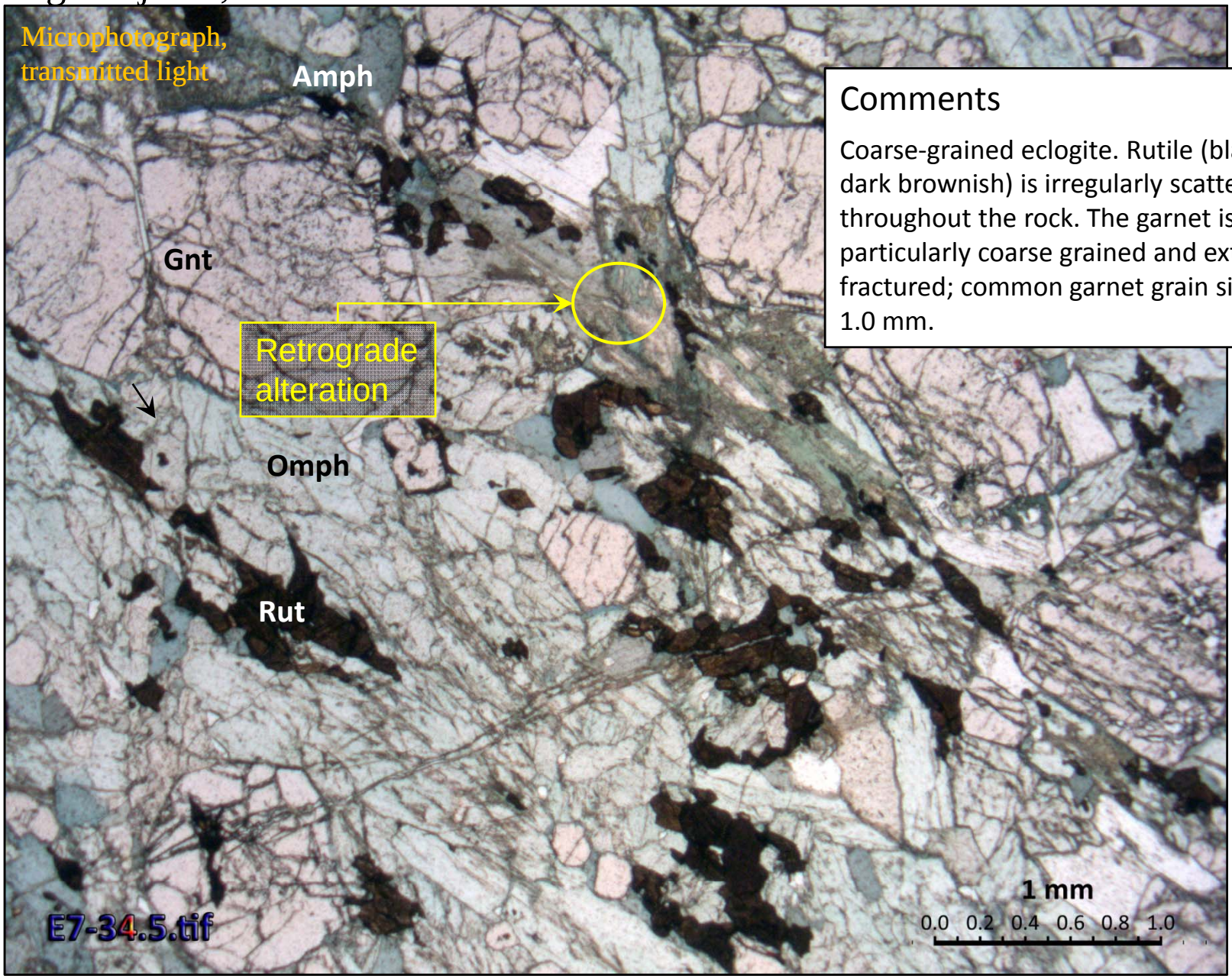
Thin-section Dh7/34.5m

Comments

Coarse-grained, garnet-rich eclogite with retrograde alteration along fractures. This eclogite variety is fairly rutile-rich but is not typical rutile ore eclogite due to the large garnet grain-size.

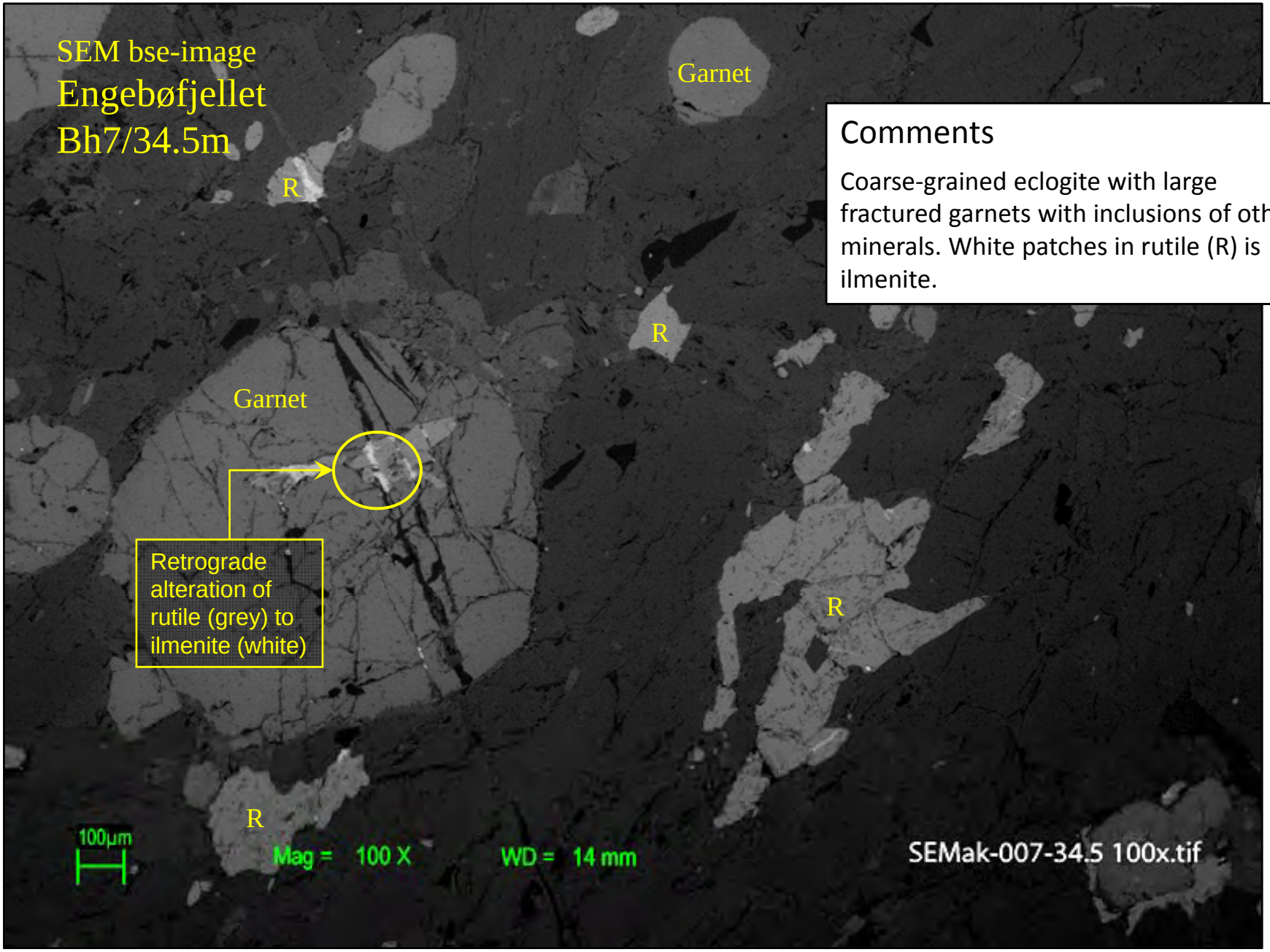
40 wt.% garnet (based on image processing of digital photos).

Engebøfjellet, Bh7/34.5m



Comments

Coarse-grained eclogite. Rutile (black to dark brownish) is irregularly scattered throughout the rock. The garnet is particularly coarse grained and extensively fractured; common garnet grain size is 0.5-1.0 mm.

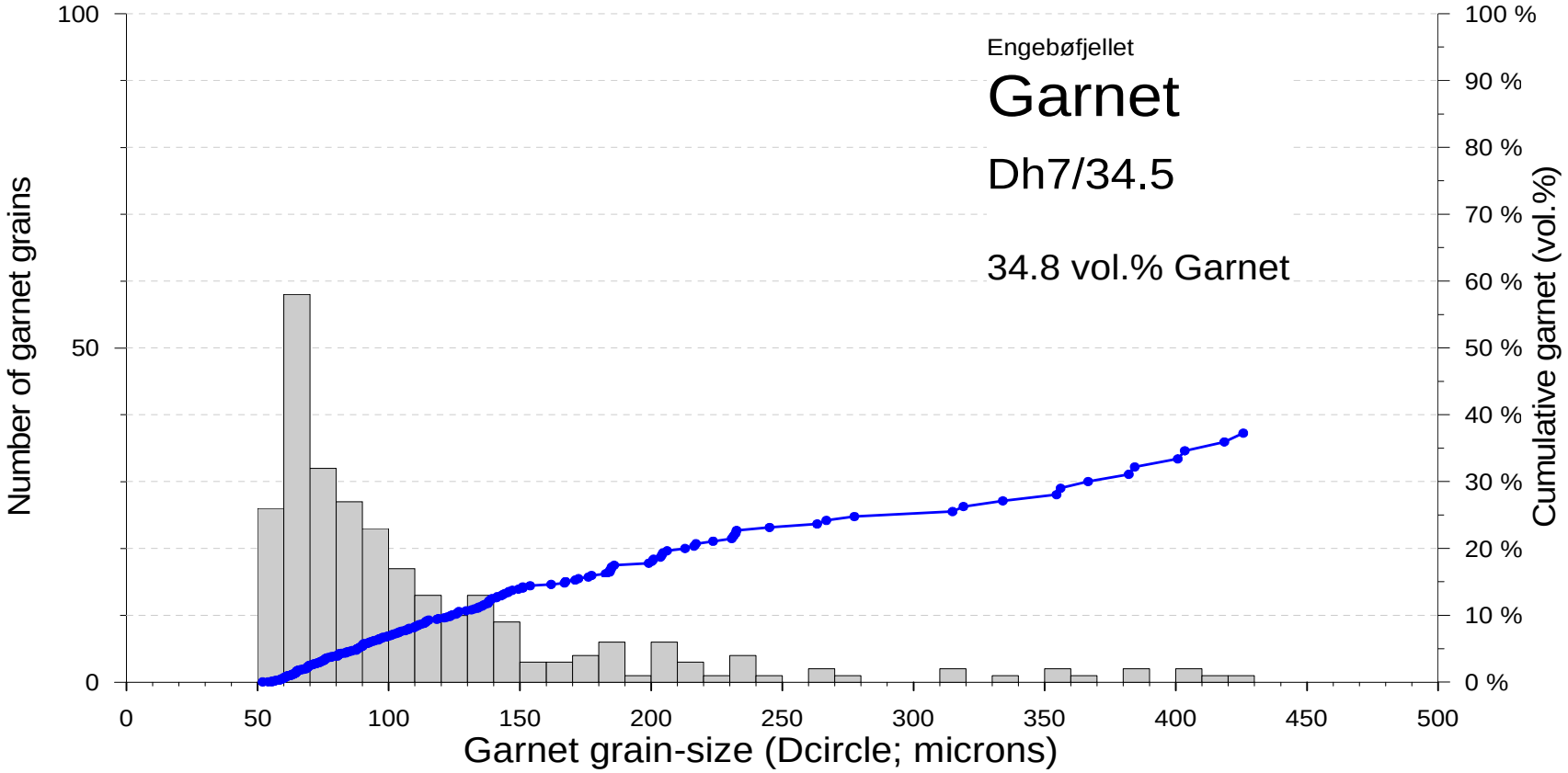


Comments

Coarse-grained eclogite with large fractured garnets with inclusions of other minerals. White patches in rutile (R) is ilmenite.

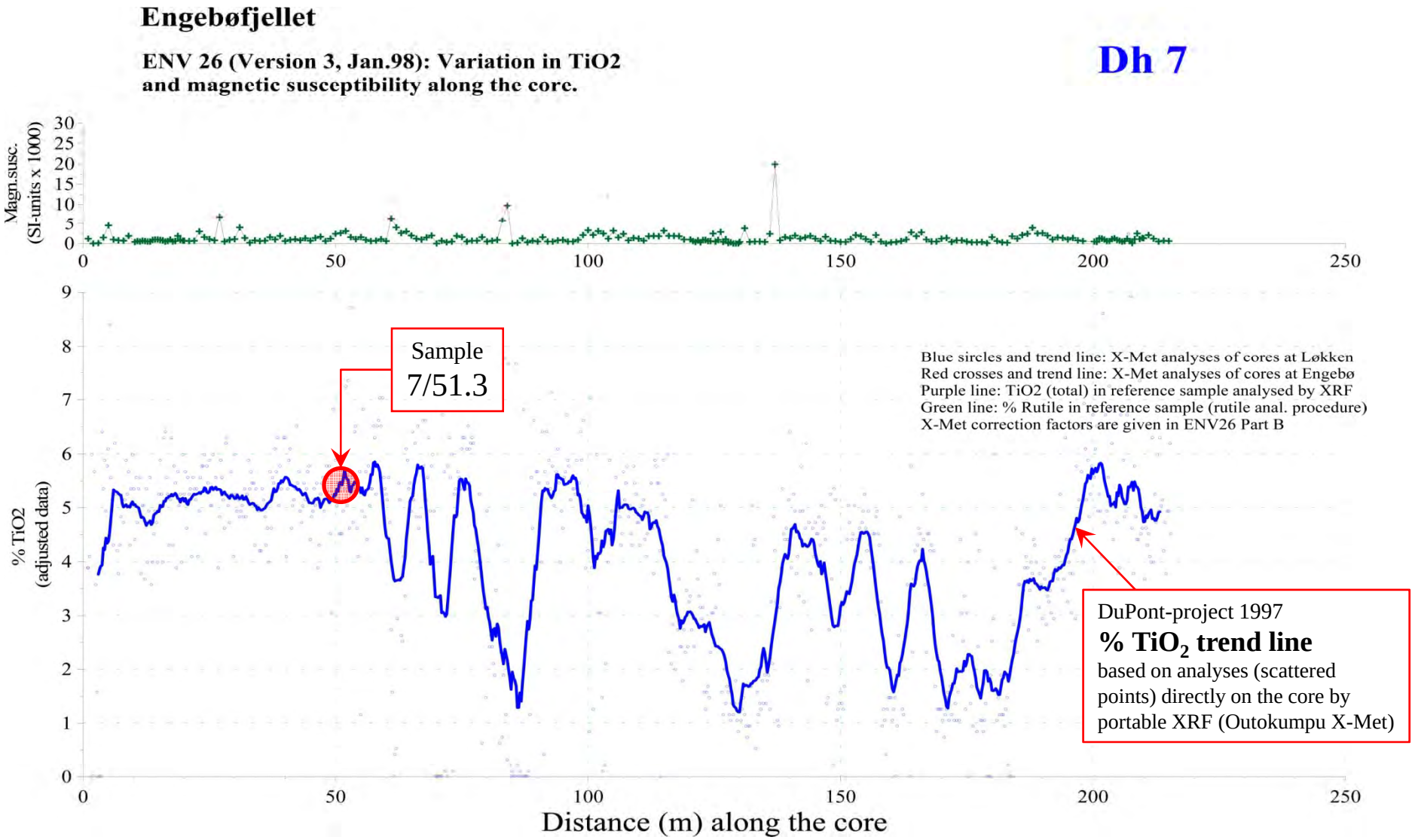
Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6. The resolution of the present method is low and the finest grains are not picked up. This sample has exceptionably coarse-grained garnets that are out of proportion with the design of the diagram. The garnet 50 vol. % boundary is above 450 microns.



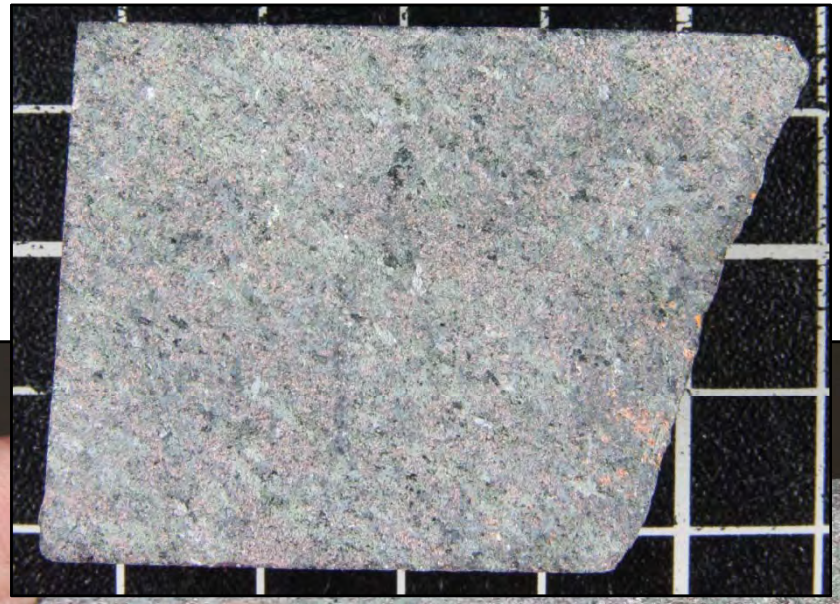
Engebøfjellet core sample information

Sample Dh7/51.3m



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Massive to foliated eclogite. The sample 7/51.3 is probably fairly representative for a significant volume of eclogite in this part of the deposit, although the neighbouring core is heterogeneous in terms of modal composition and grain-size and is partly foliated. The rock is locally retrograded along fractures as well as diffusely infiltrated into the rock, but retrogression is probably not seriously affecting the overall character of the rock.



Engebøfjellet, Bh7/51.3m

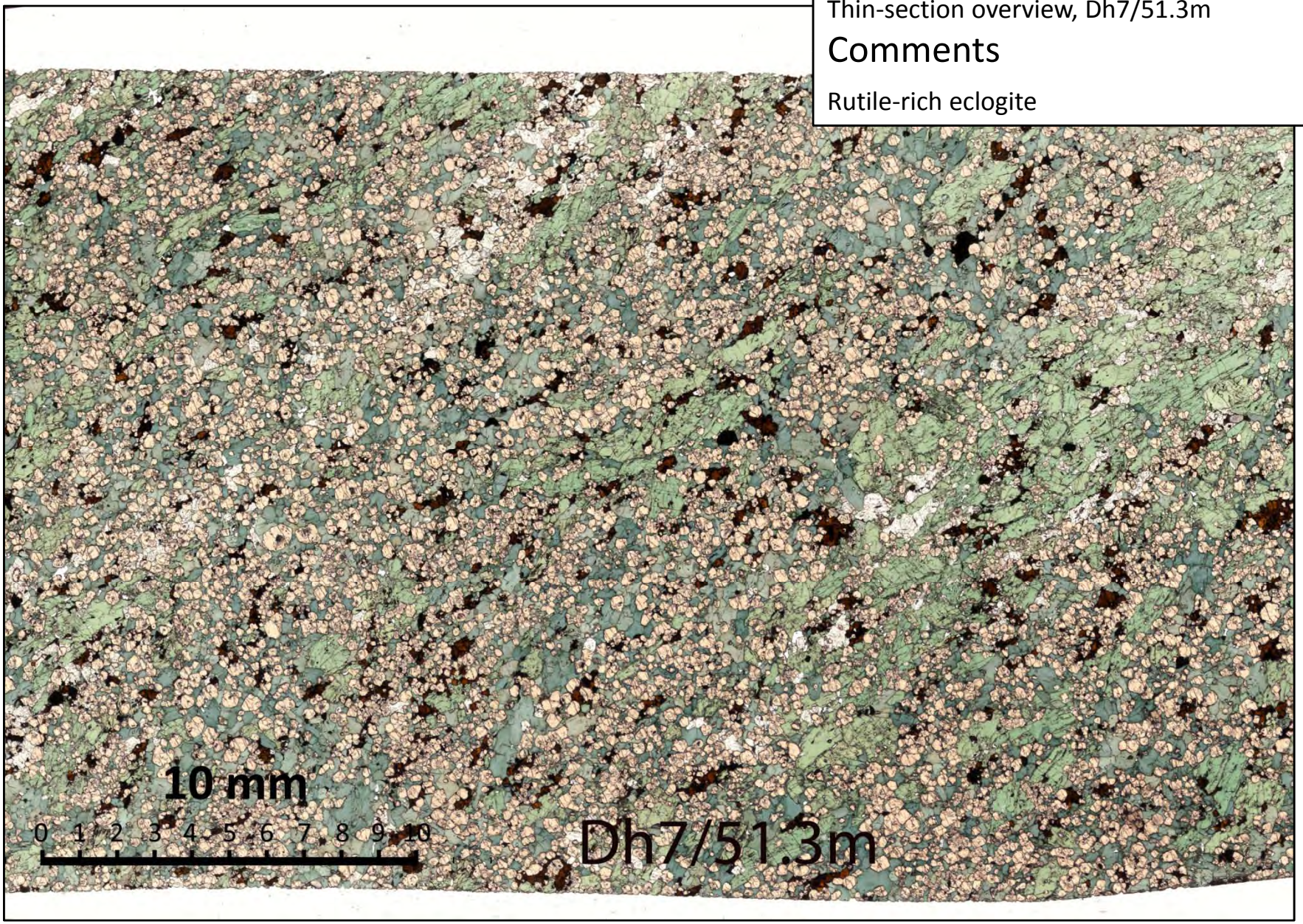
Key information

- Slightly foliated to massive ferro-eclogite
- Magnetic susceptibility: 0.00355 (SI-units)
- Specific gravity: 3.56 g/cm^3
- 2.3 % TiO_2 , 21.3 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

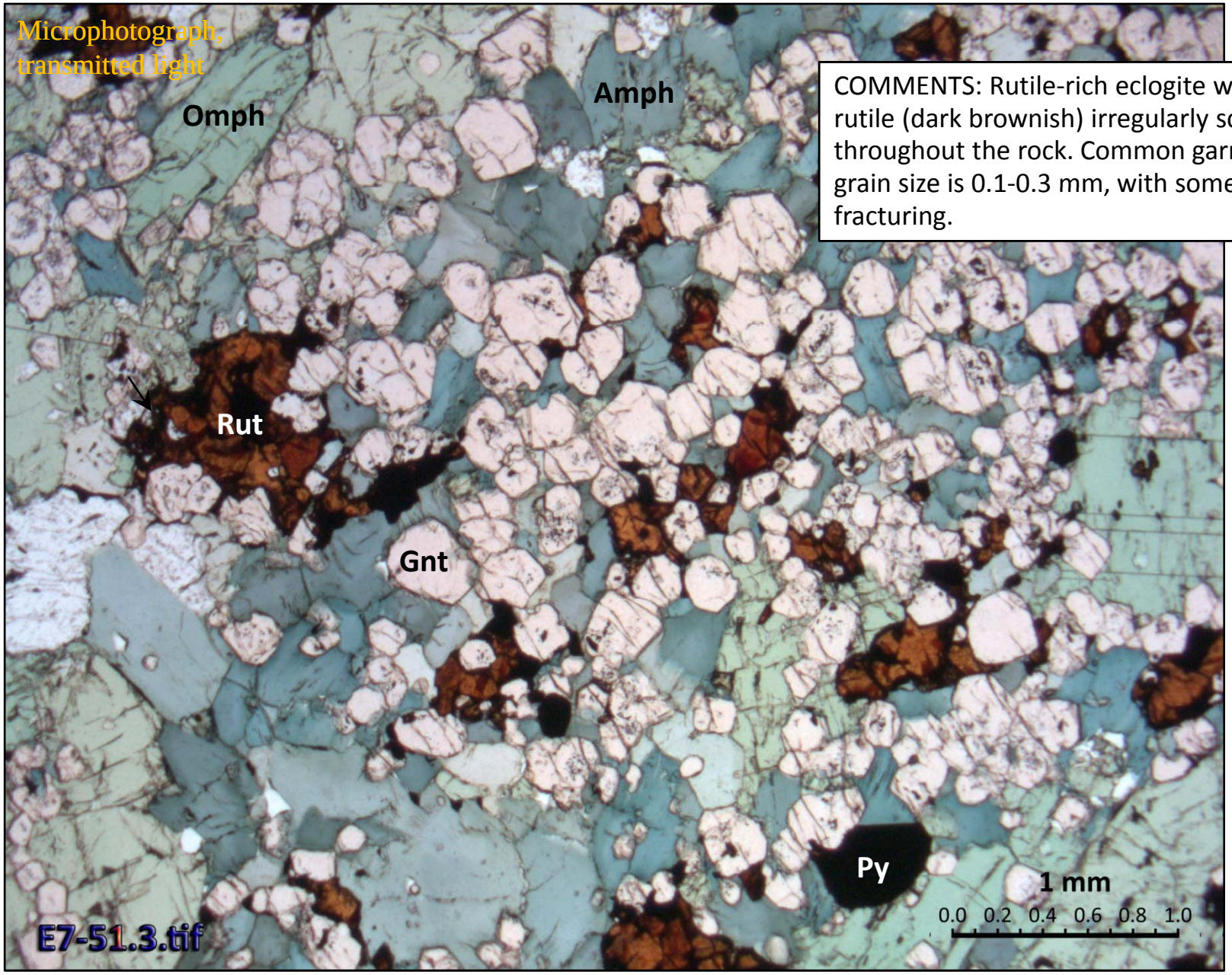
Thin-section overview, Dh7/51.3m

Comments

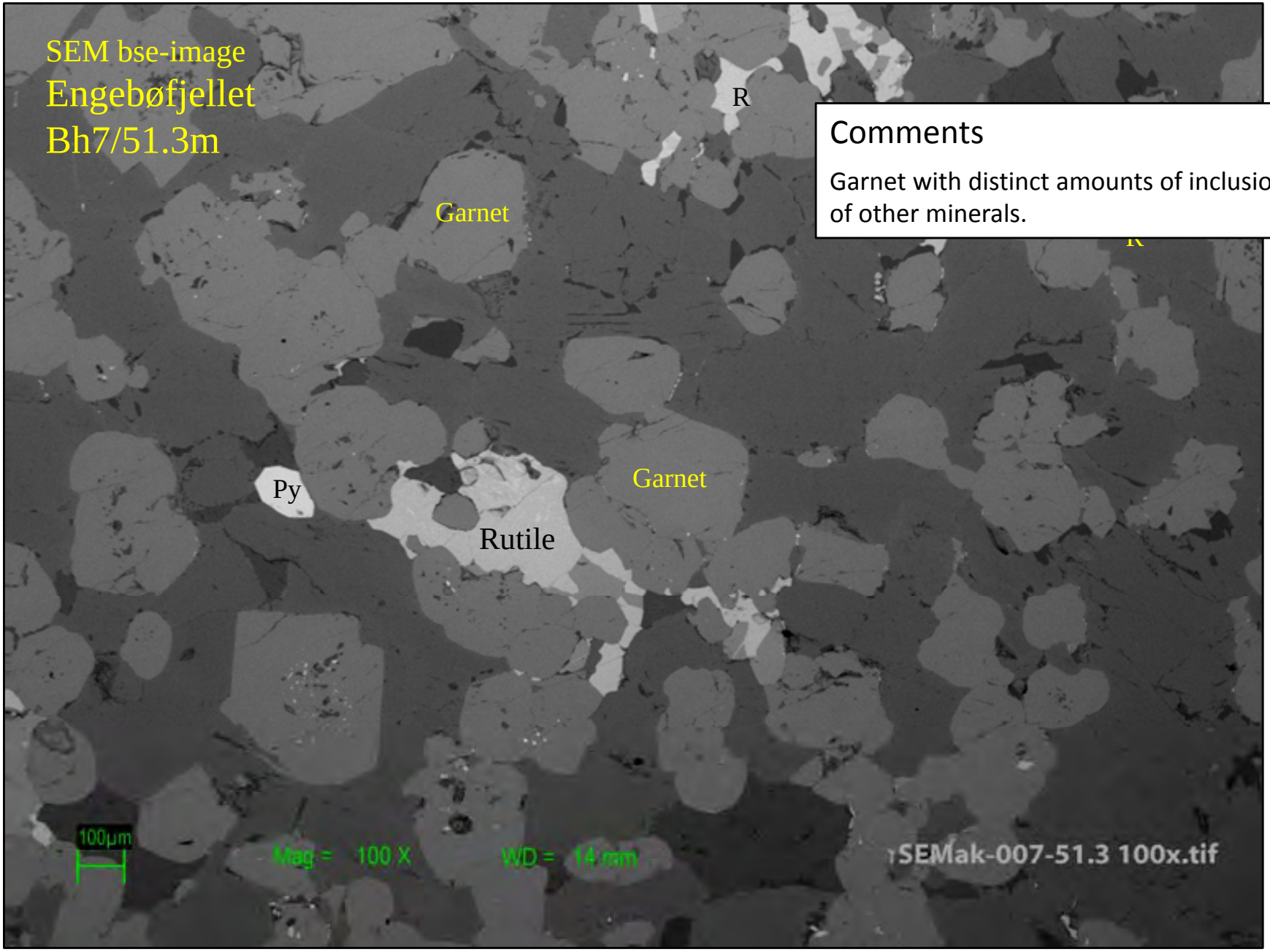
Rutile-rich eclogite



Engebøfjellet, Bh7/51.3m



COMMENTS: Rutile-rich eclogite with rutile (dark brownish) irregularly scattered throughout the rock. Common garnet grain size is 0.1-0.3 mm, with some fracturing.

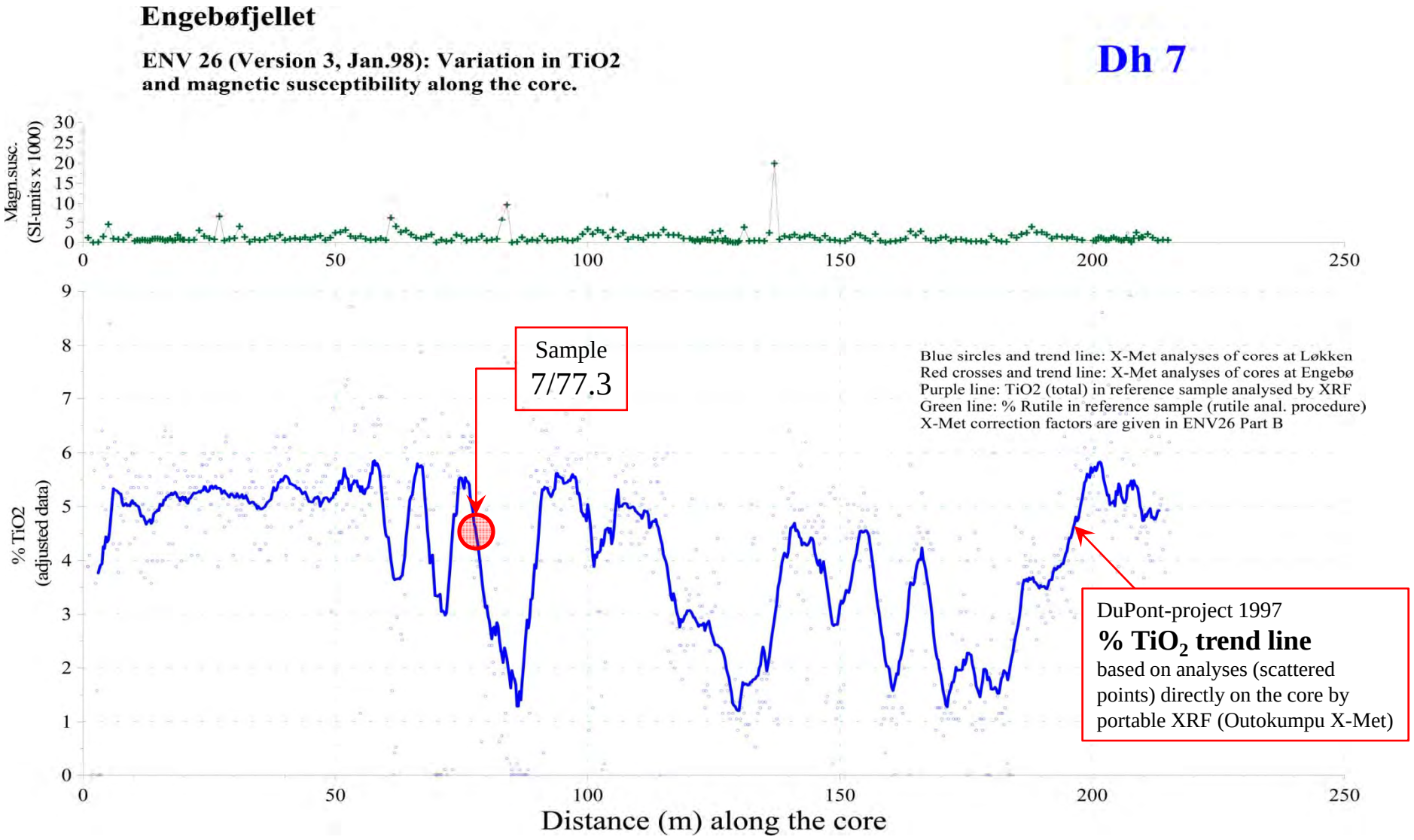


Comments

Garnet with distinct amounts of inclusions of other minerals.

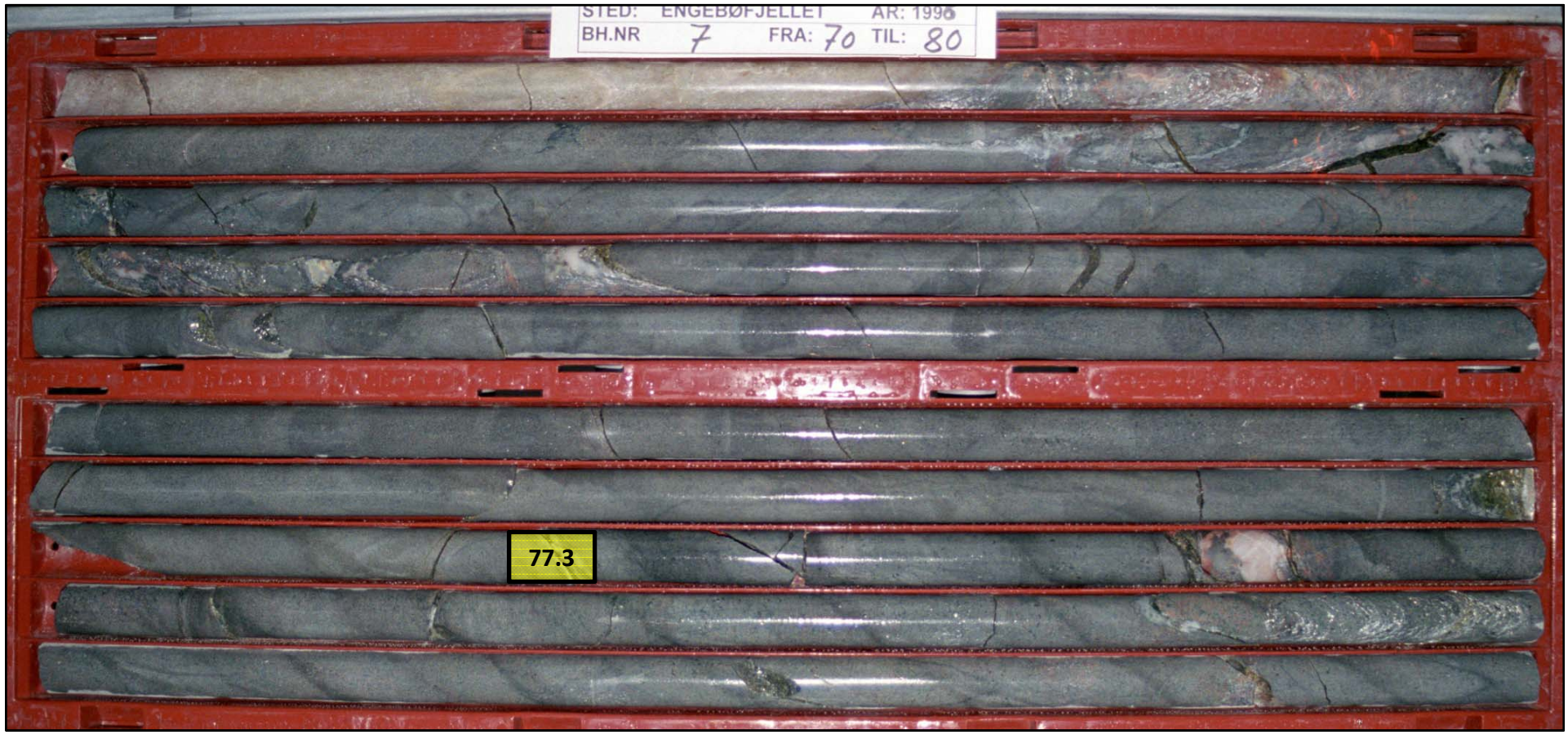
Engebøfjellet core sample information

Sample Dh7/77.3m

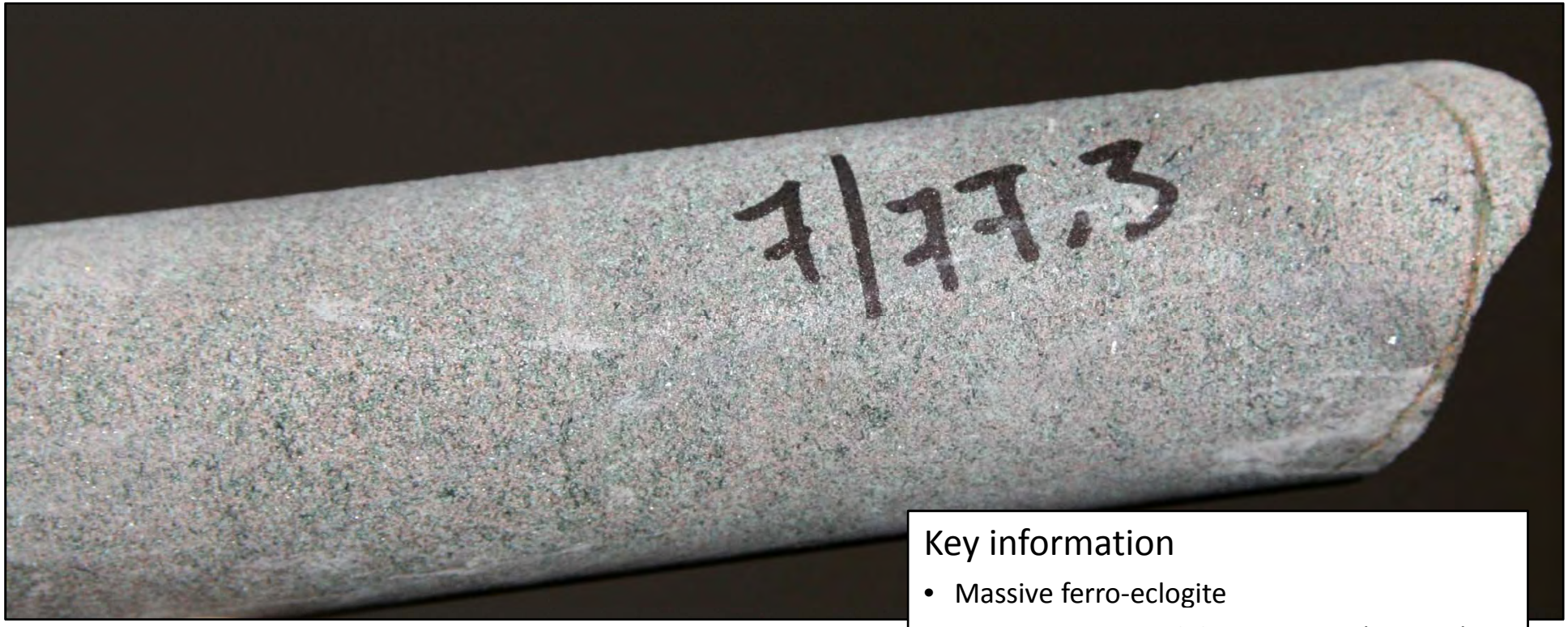


Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Massive eclogite (ore type; ferro-eclogite) from a heterogeneous part of the deposit. No significant retrograde alteration is observed.

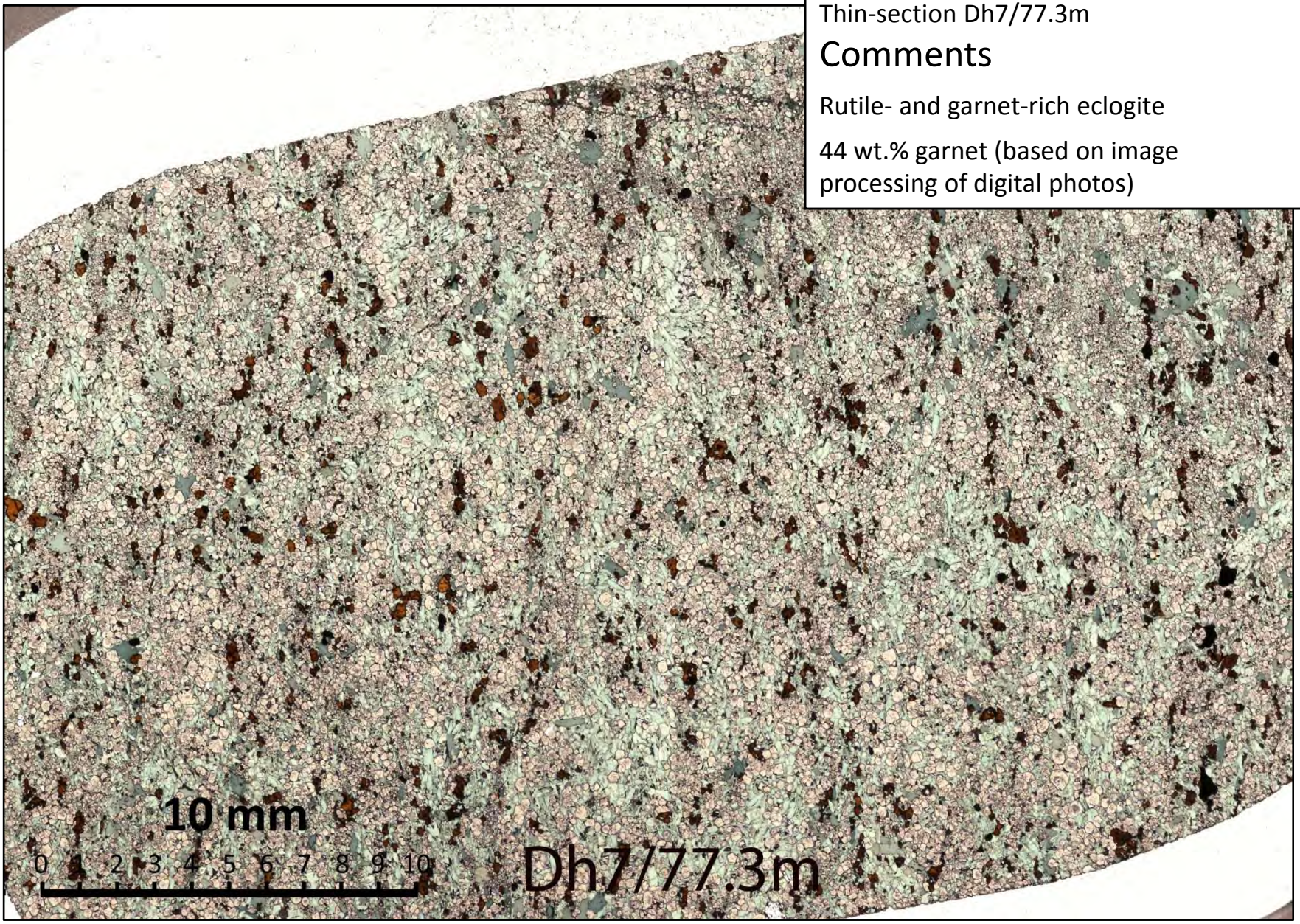


Engebøfjellet, Bh7/77.3m



Key information

- Massive ferro-eclogite
- Magnetic susceptibility: 0.00126 (SI-units)
- Specific gravity: 3.65 g/cm^3
- 2.6 % TiO_2 , 19.1 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)



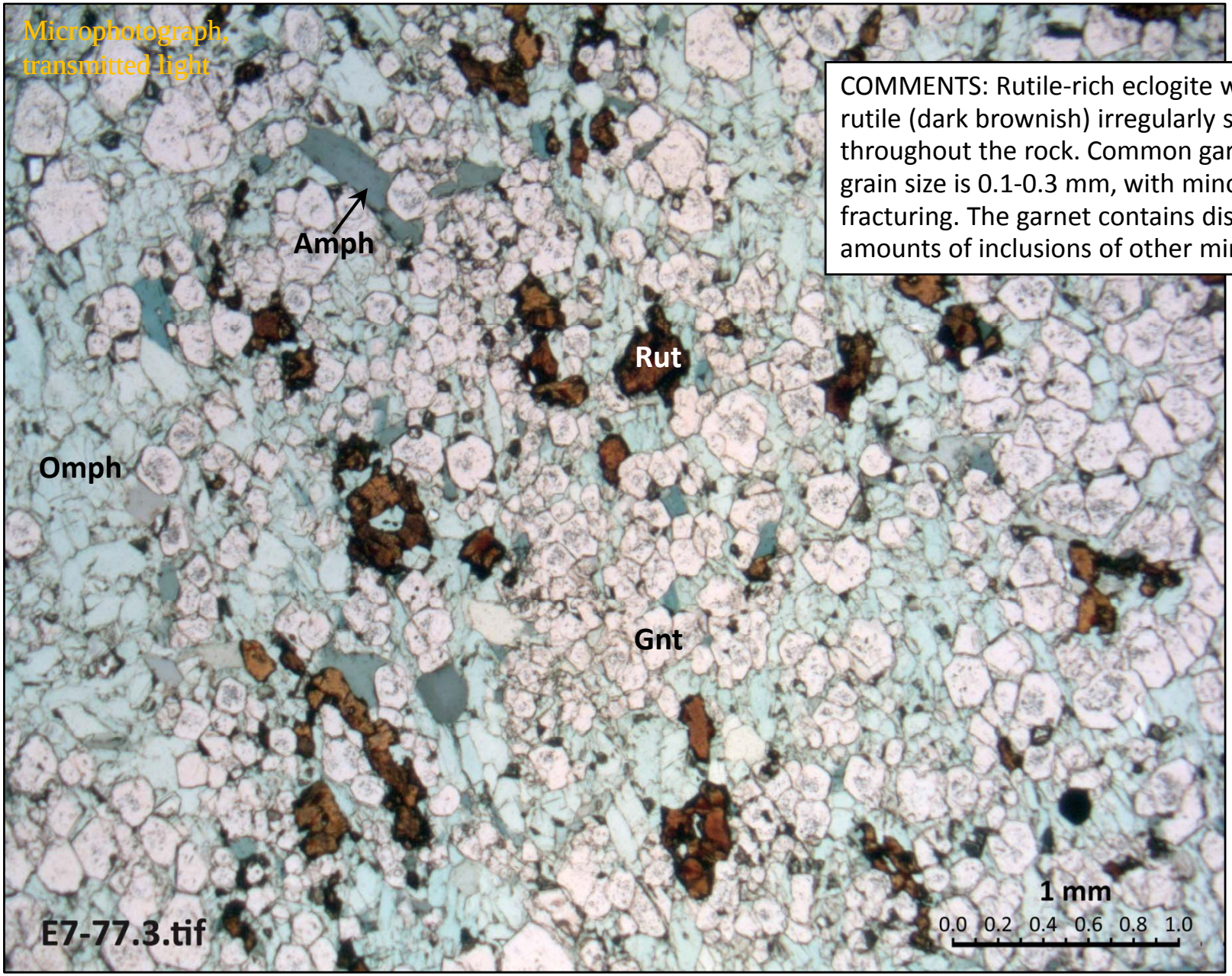
Thin-section Dh7/77.3m

Comments

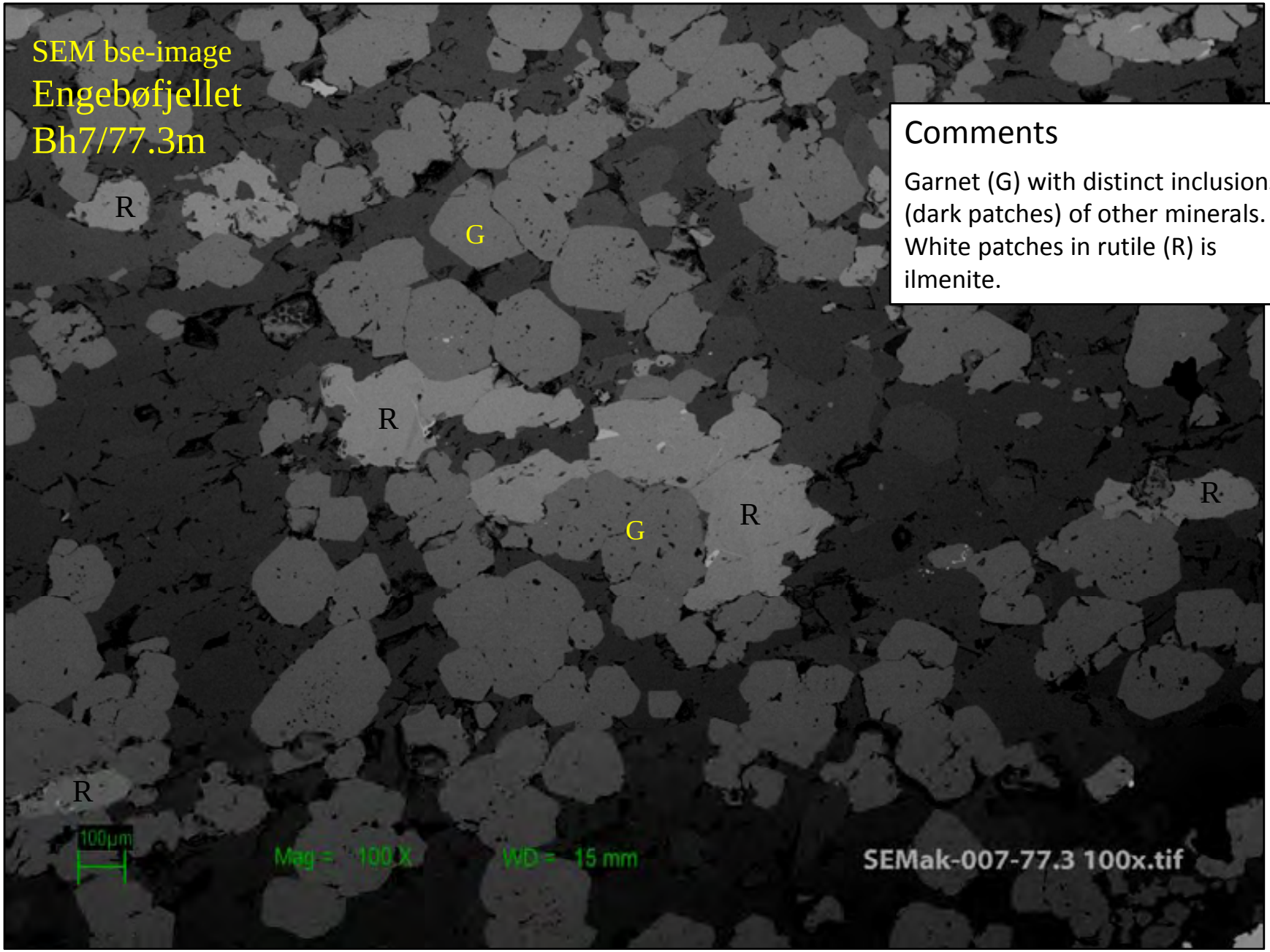
Rutile- and garnet-rich eclogite

44 wt.% garnet (based on image processing of digital photos)

Engebøfjellet, Bh7/77.3m



COMMENTS: Rutile-rich eclogite with rutile (dark brownish) irregularly scattered throughout the rock. Common garnet grain size is 0.1-0.3 mm, with minor fracturing. The garnet contains distinct amounts of inclusions of other minerals.

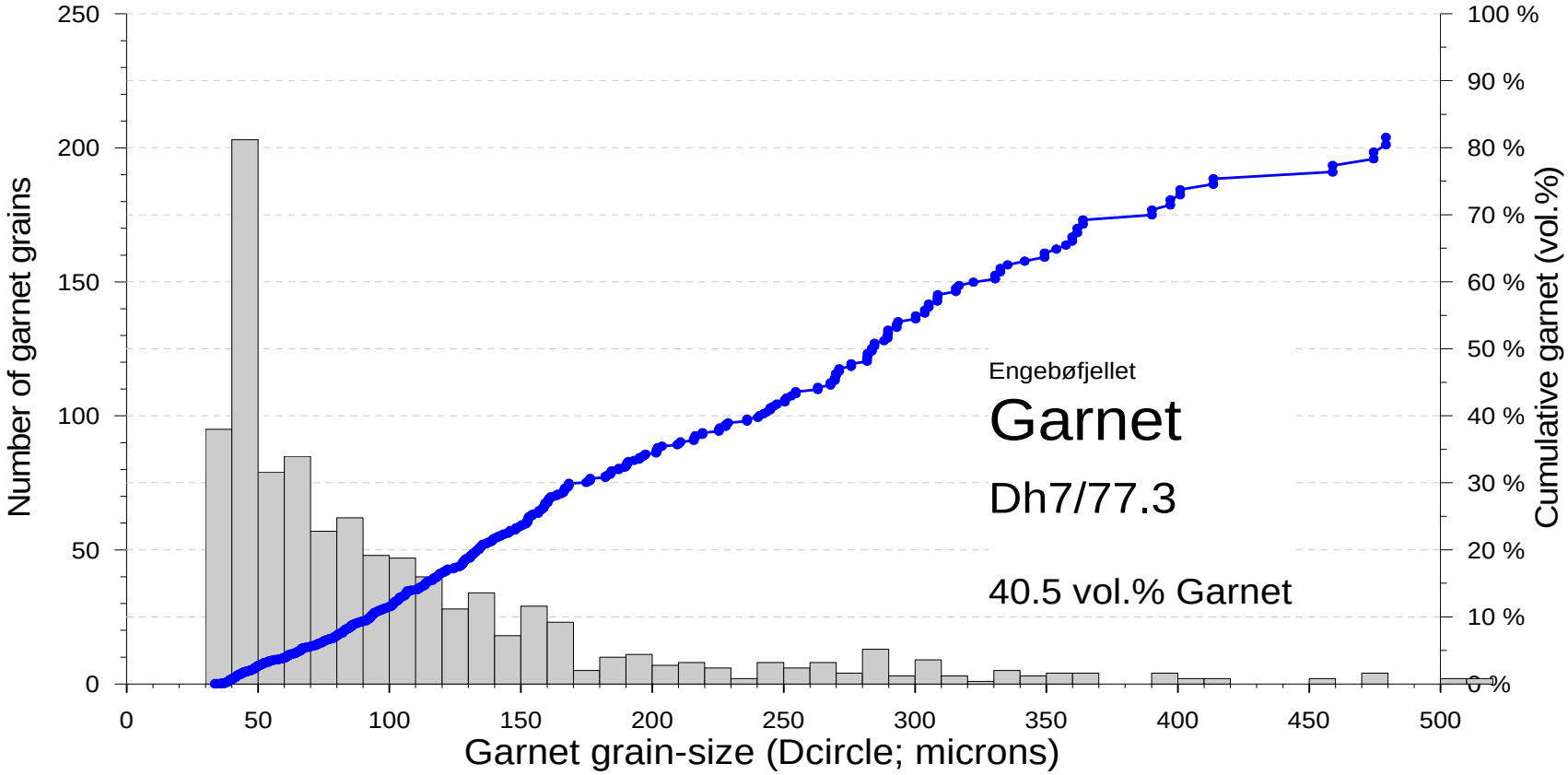


Comments

Garnet (G) with distinct inclusions (dark patches) of other minerals. White patches in rutile (R) is ilmenite.

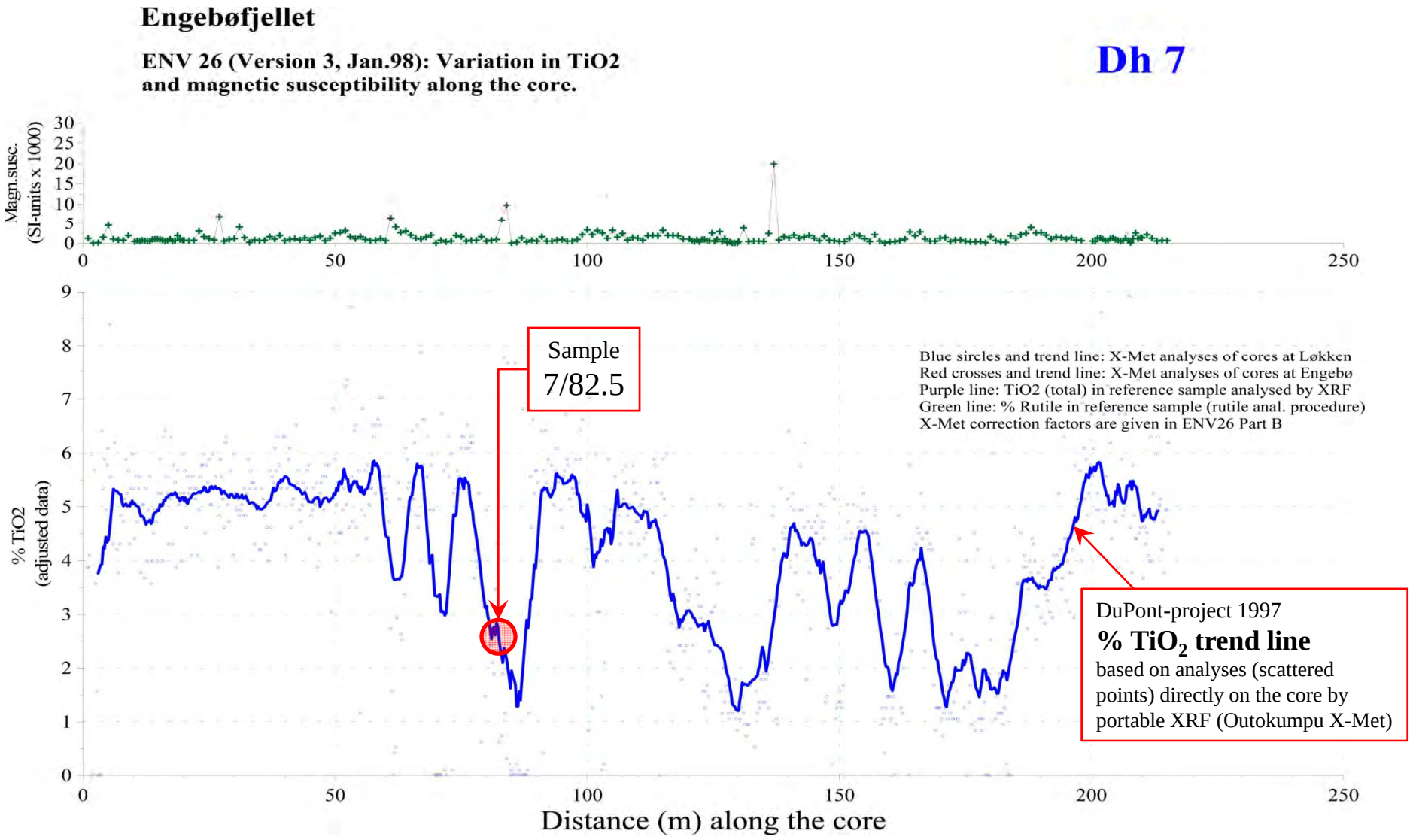
Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet present is less than 290 microns. However, since grains attached to each other is registered as one larger grain by this method, the real garnet 50%-boundary is probably below 290 microns.



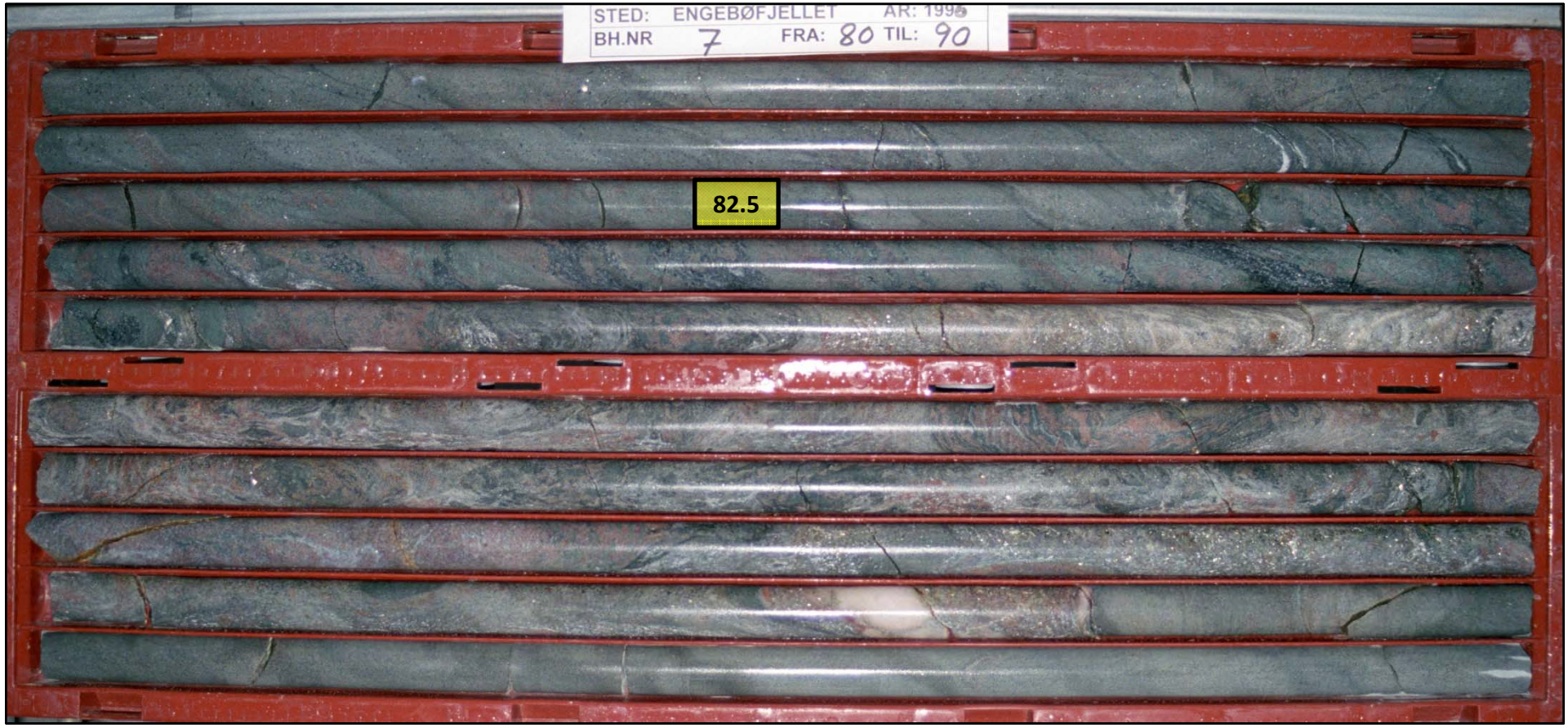
Engebøfjellet core sample information

Sample Dh7/82.5m

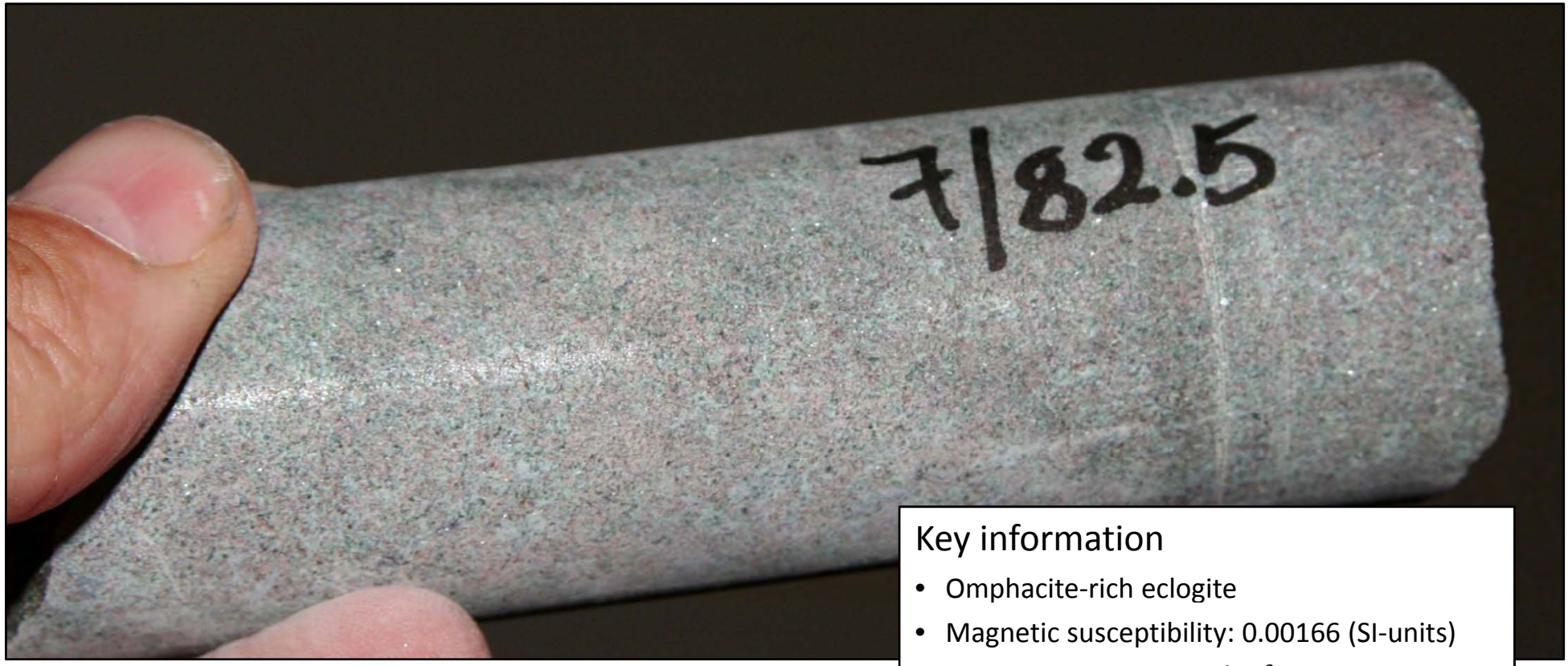


Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Massive low-TiO_2 eclogite from a heterogeneous part of the deposit; the heterogeneity is due to foliation and banding, variable content of major minerals and grain size variations. The sample is not representative for a significant volume of eclogite in this part of the deposit. No significant retrograde alteration is observed in the sample.



Engebøfjellet, Bh7/82.5m



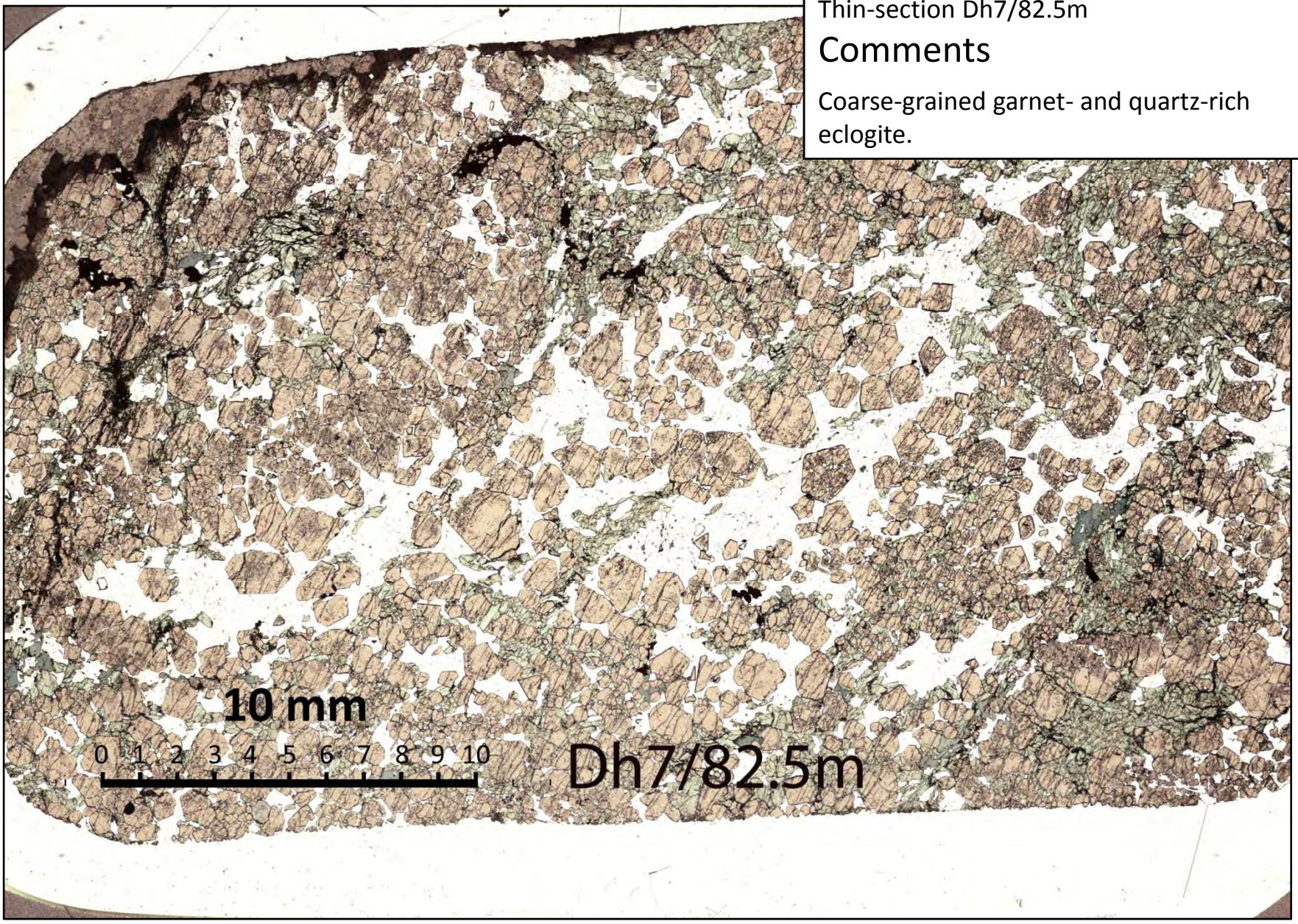
Key information

- Omphacite-rich eclogite
- Magnetic susceptibility: 0.00166 (SI-units)
- Specific gravity: 3.54 g/cm^3
- 1.1 % TiO_2 , 18.0 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

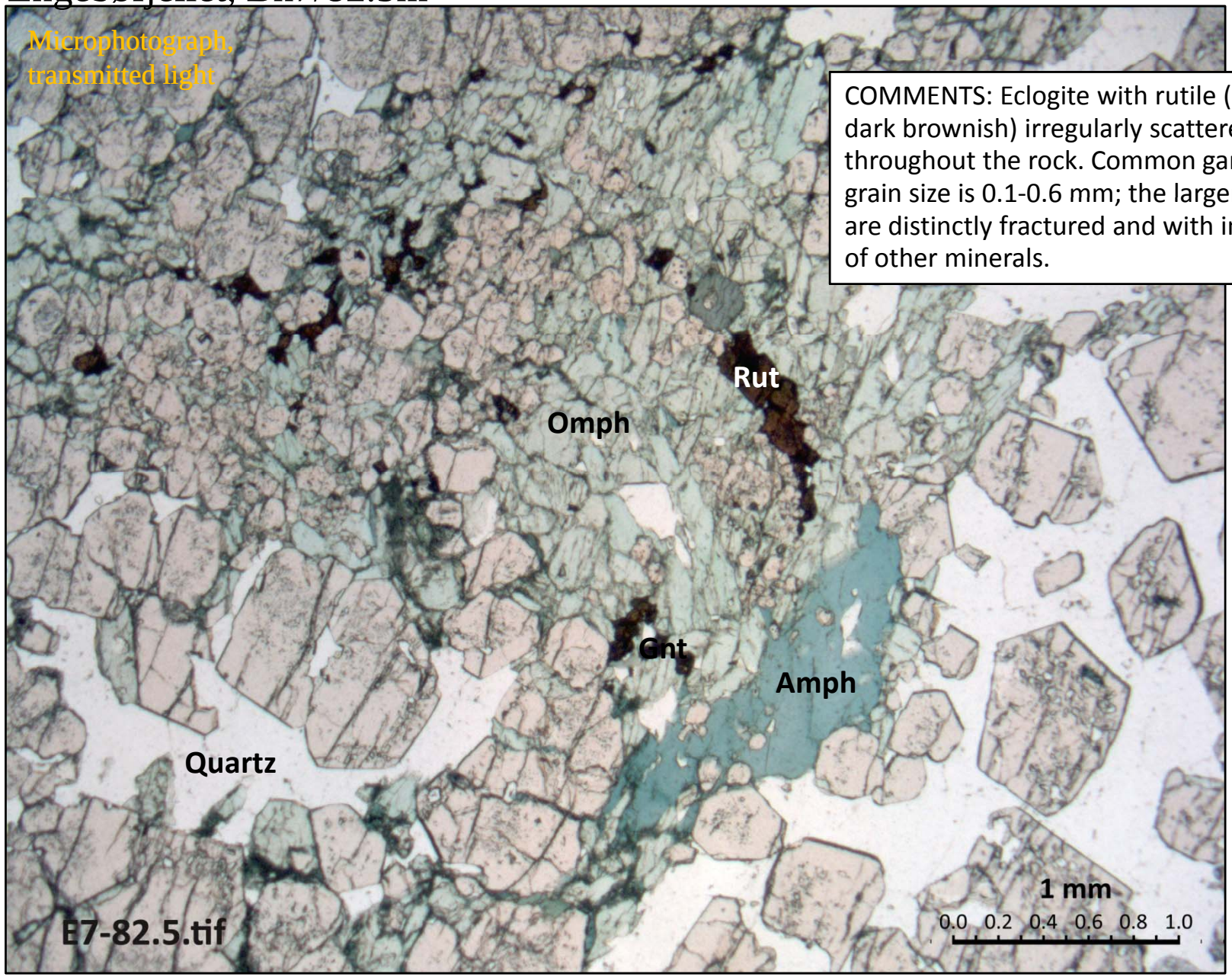
Thin-section Dh7/82.5m

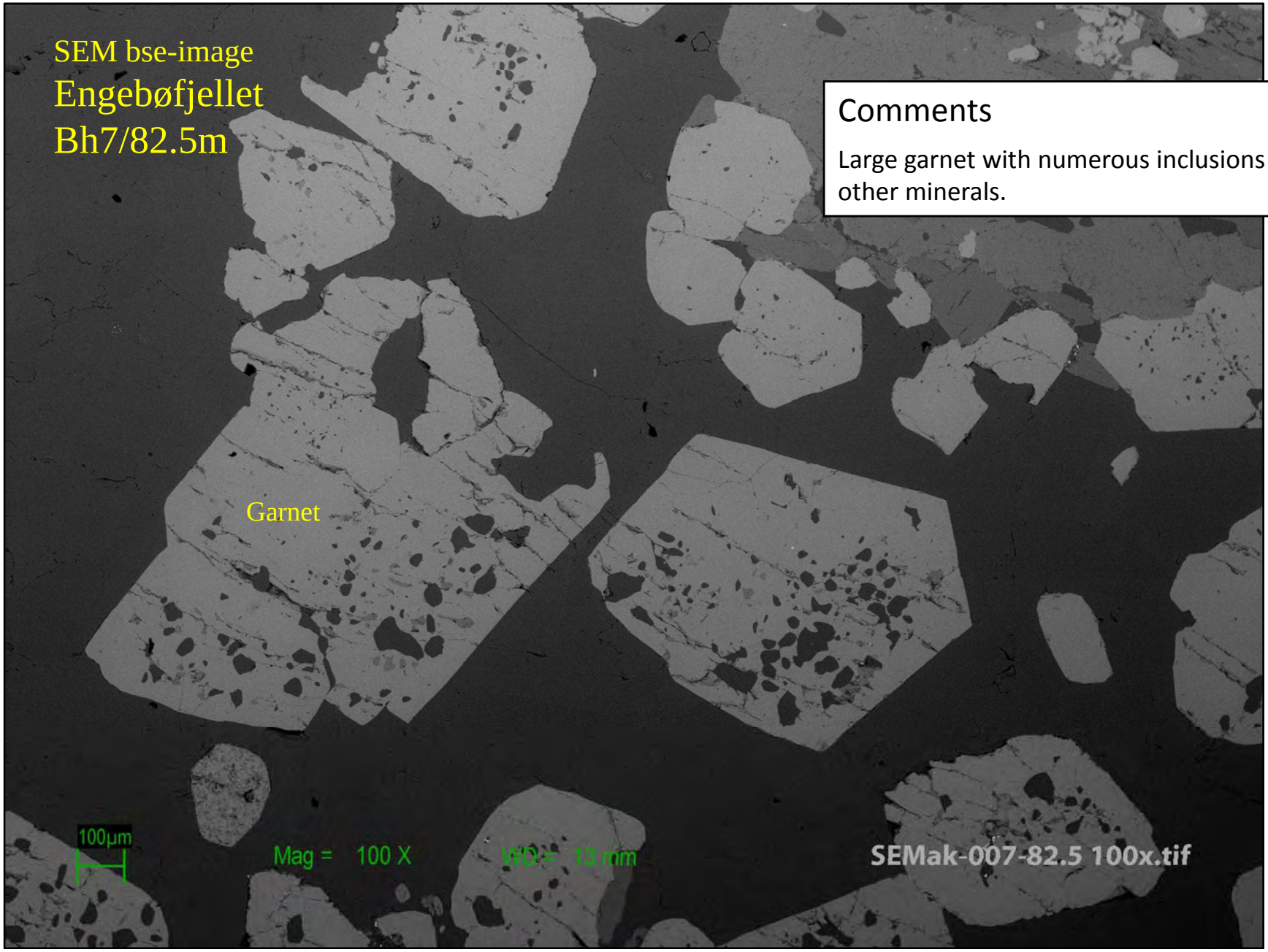
Comments

Coarse-grained garnet- and quartz-rich eclogite.



Engebøfjellet, Bh7/82.5m



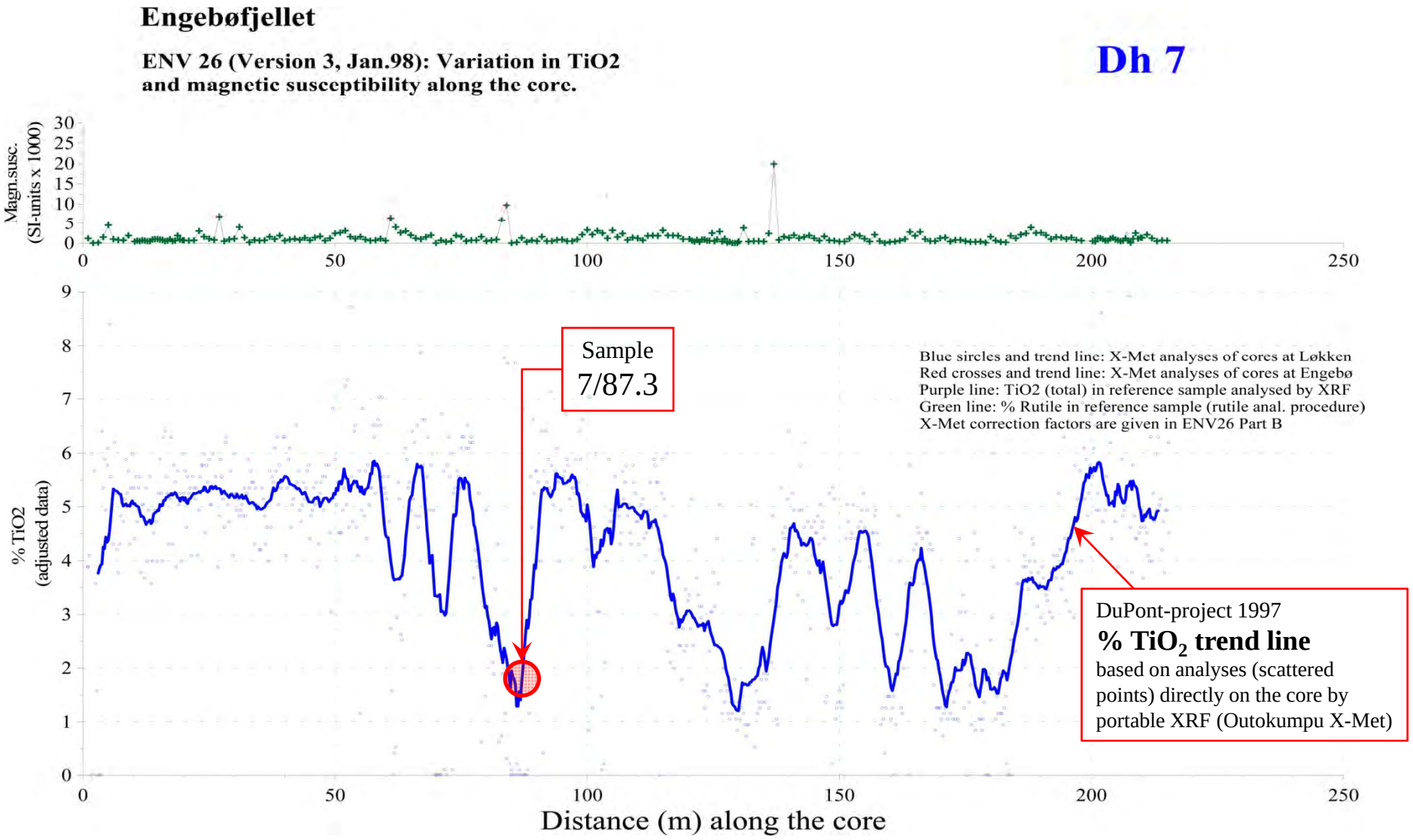


Comments

Large garnet with numerous inclusions of other minerals.

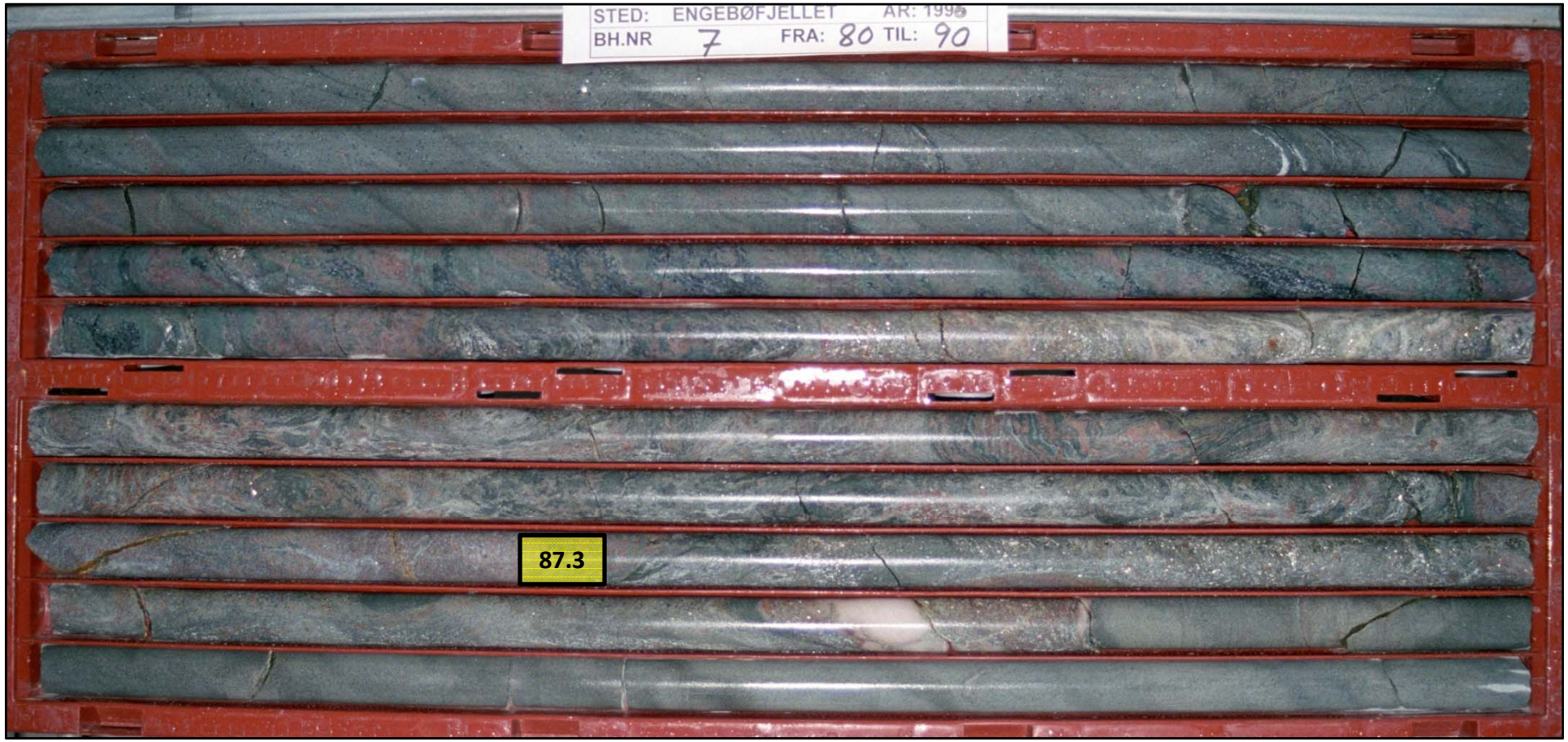
Engebøfjellet core sample information

Sample Dh7/87.3m



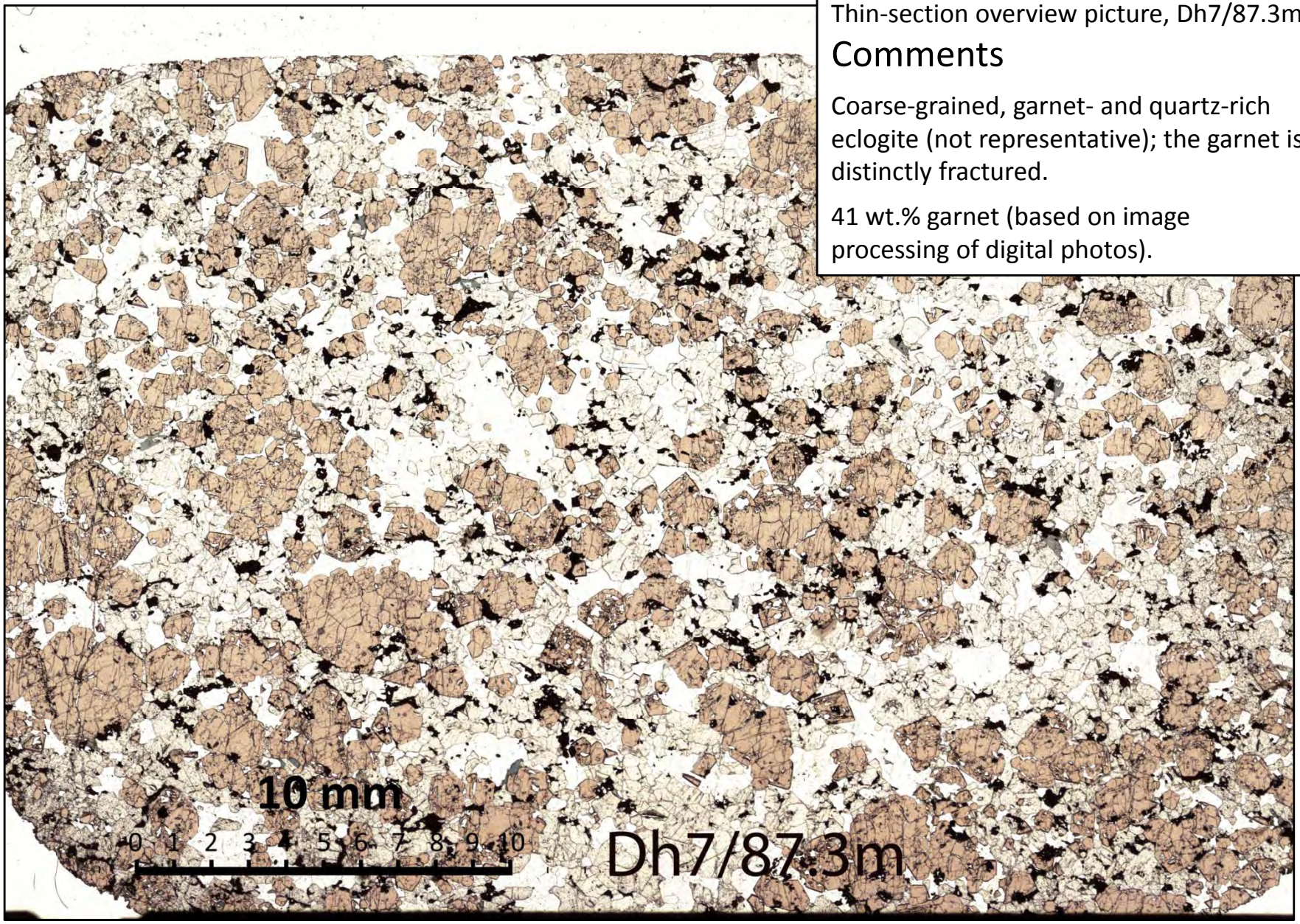
Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Massive low-TiO_2 eclogite from a heterogeneous part of the deposit; the heterogeneity is due to foliation and banding, variable content of major minerals and grain-size variations. The sample is probably not representative for a large volume of eclogite in this part of the deposit. No significant retrograde alteration is observed in the sample.



Key information

- Coarse-grained garnet-quartz rock
- Magnetic susceptibility: 0.00199 (SI-units)
- Specific gravity: 3.29 g/cm^3
- 3.1 % TiO_2 , 15.9 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)



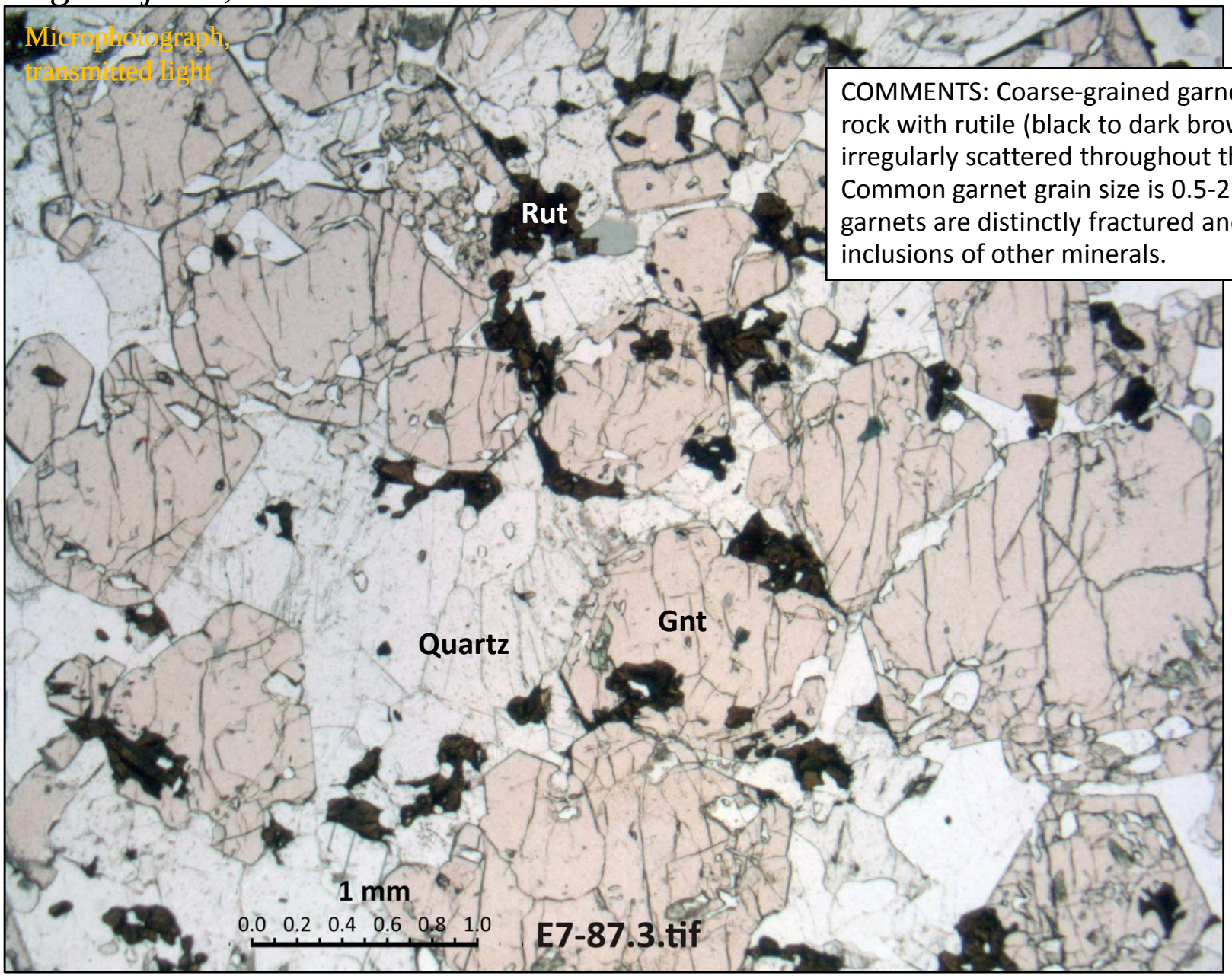
Thin-section overview picture, Dh7/87.3m

Comments

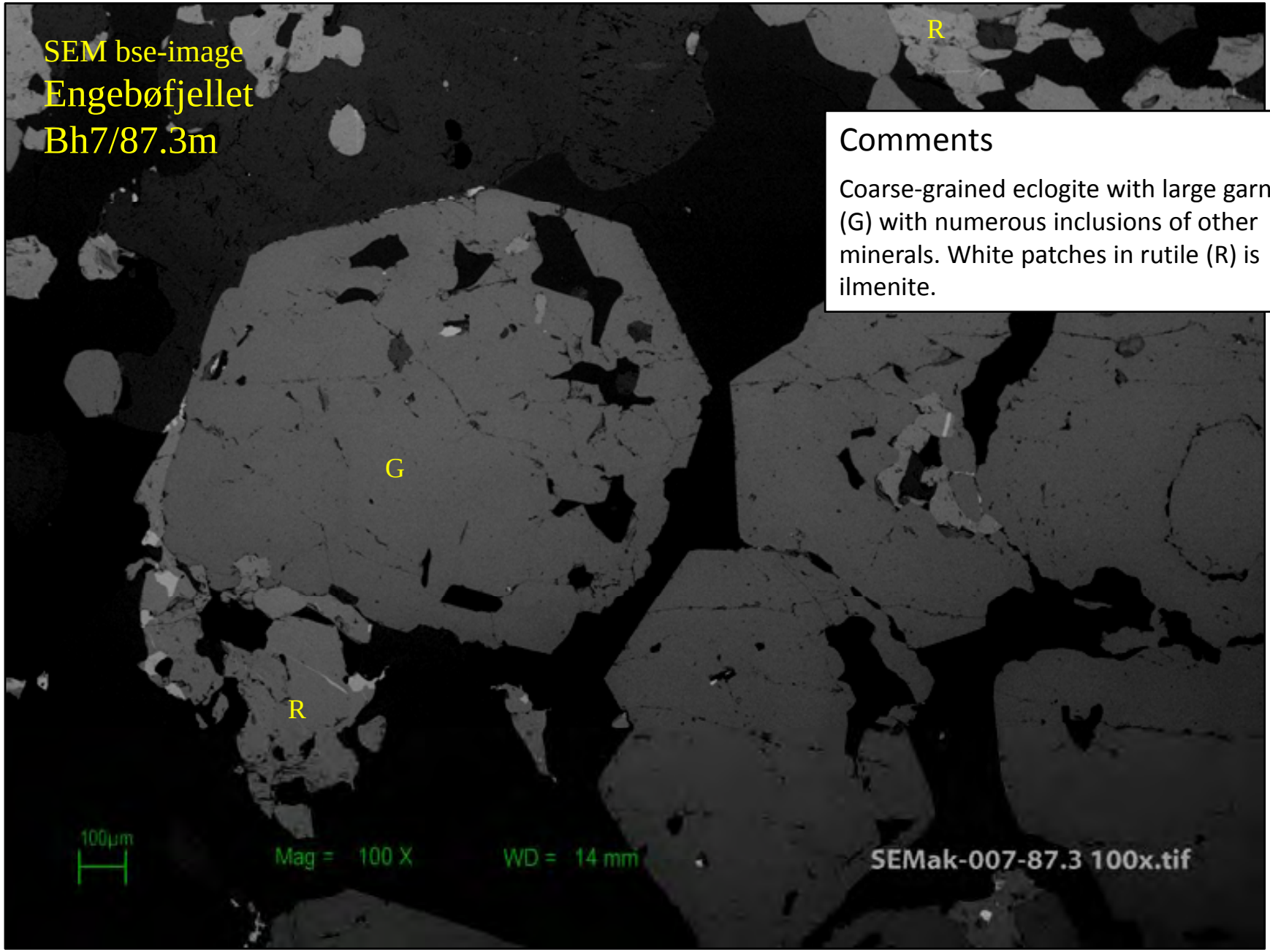
Coarse-grained, garnet- and quartz-rich eclogite (not representative); the garnet is distinctly fractured.

41 wt.% garnet (based on image processing of digital photos).

Engebøfjellet, Bh7/87.3m



COMMENTS: Coarse-grained garnet-quartz rock with rutile (black to dark brownish) irregularly scattered throughout the rock. Common garnet grain size is 0.5-2 mm; the garnets are distinctly fractured and with inclusions of other minerals.

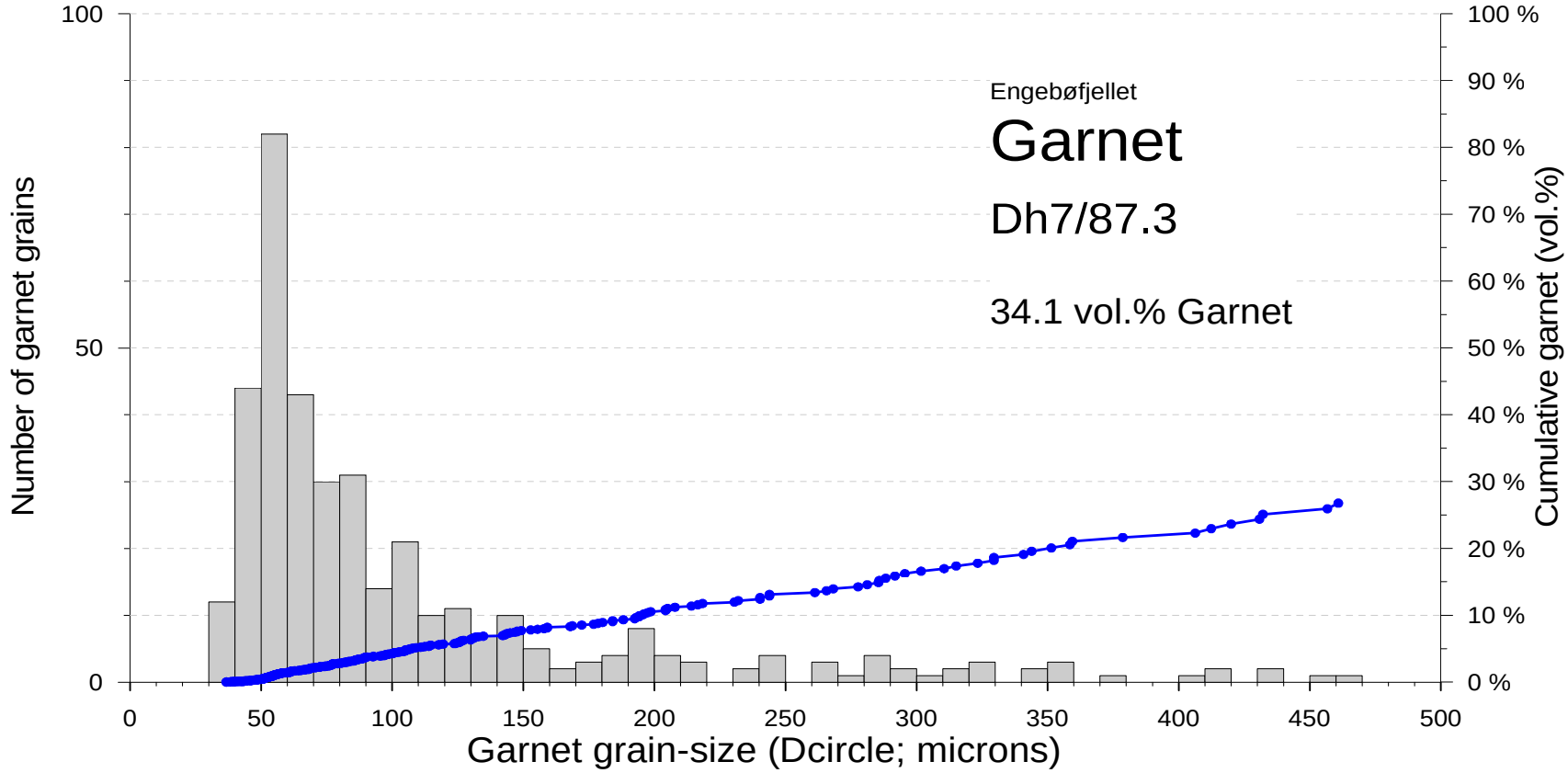


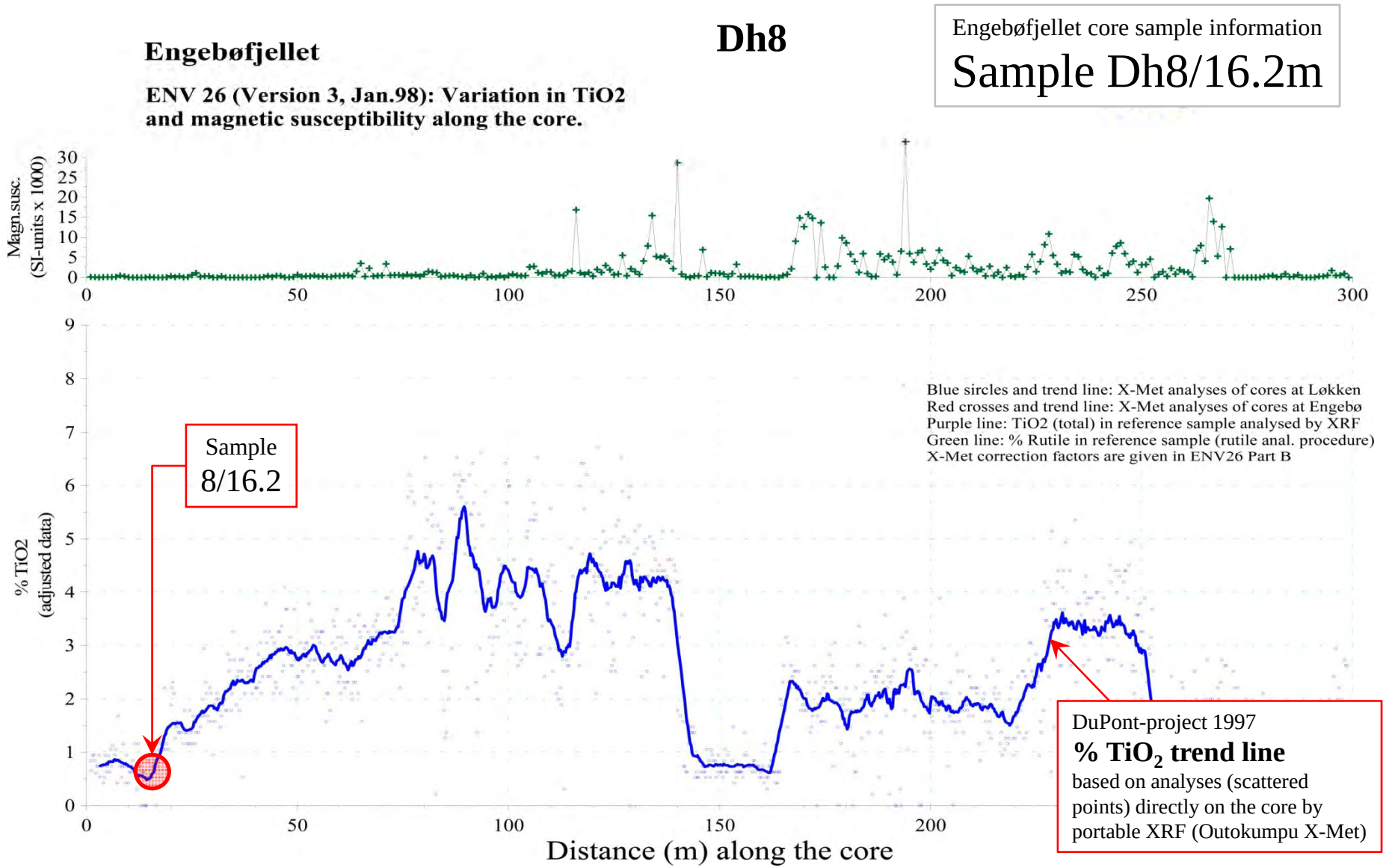
Comments

Coarse-grained eclogite with large garnets (G) with numerous inclusions of other minerals. White patches in rutile (R) is ilmenite.

Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. This sample has exceptionably coarse-grained garnet and the grain-size is out of proportion with the design of the diagram.
The garnet 50 vol. % boundary is well above 500 microns.




Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2
and magnetic susceptibility along the core.
Dh8
Engebøfjellet core sample information
Sample Dh8/16.2m
Magn.susc.
(SI-units x 1000)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
9
8
7
6
5
4
3
2
1
0
% TiO2
(adjusted data)
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Sample
8/16.2
0
50
100
150
200
Distance (m) along the core
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Low-TiO_2 eclogite (leuco-eclogite) from a heterogeneous part of the deposit; the heterogeneity is mainly due to foliation and banding, and quartz-veins in neighbouring eclogite. The sample is probably fairly representative for leuco-eclogite from this part of the deposit.

Engebøfjellet, Bh8/16.2m

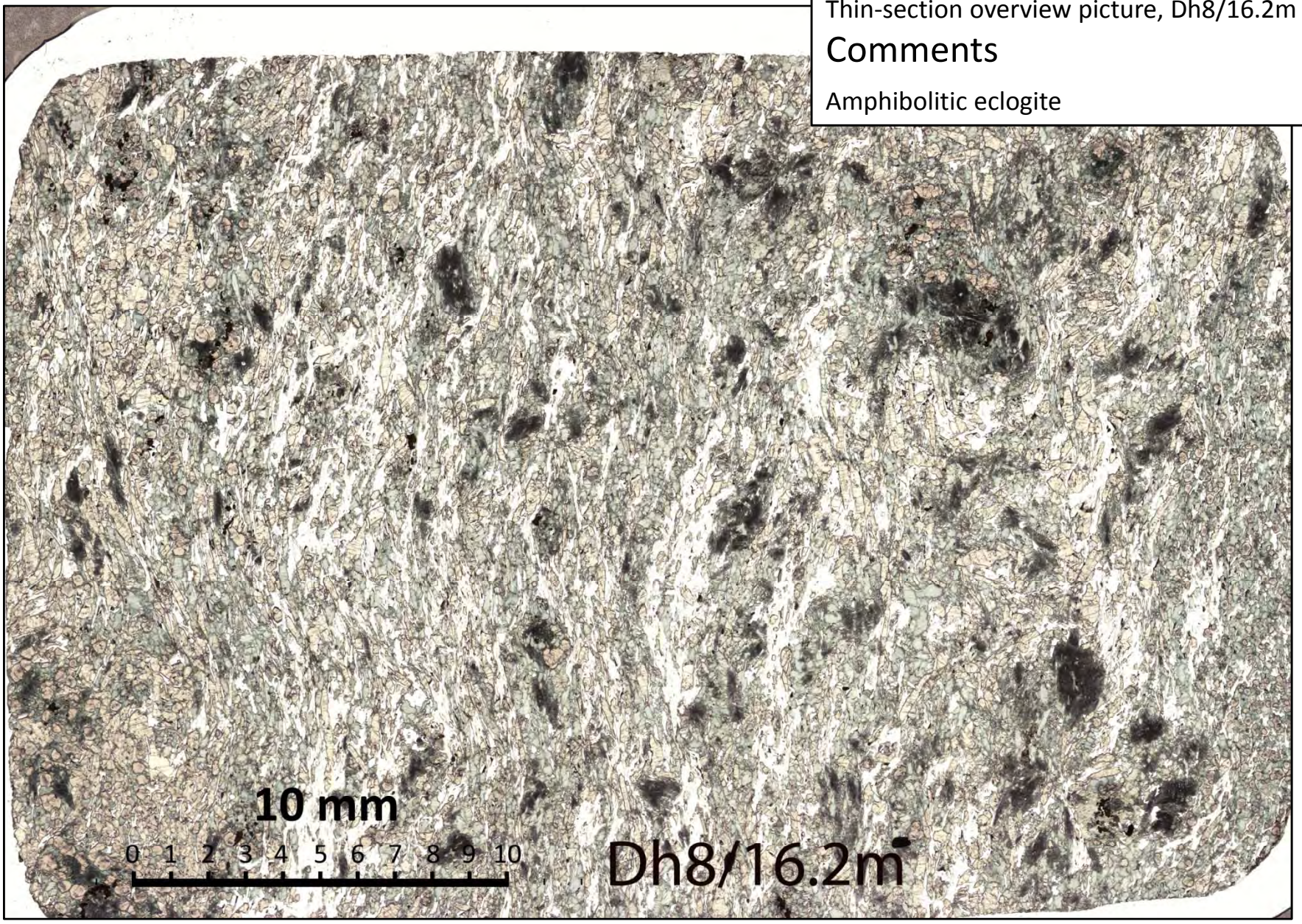
Key information

- Amphibolitic eclogite / leuco-eclogite, slightly foliated.
- Magnetic susceptibility: 0.00057 (SI-units)
- Specific gravity: 3.07 g/cm^3
- 0.3 % TiO_2 , 7.8 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

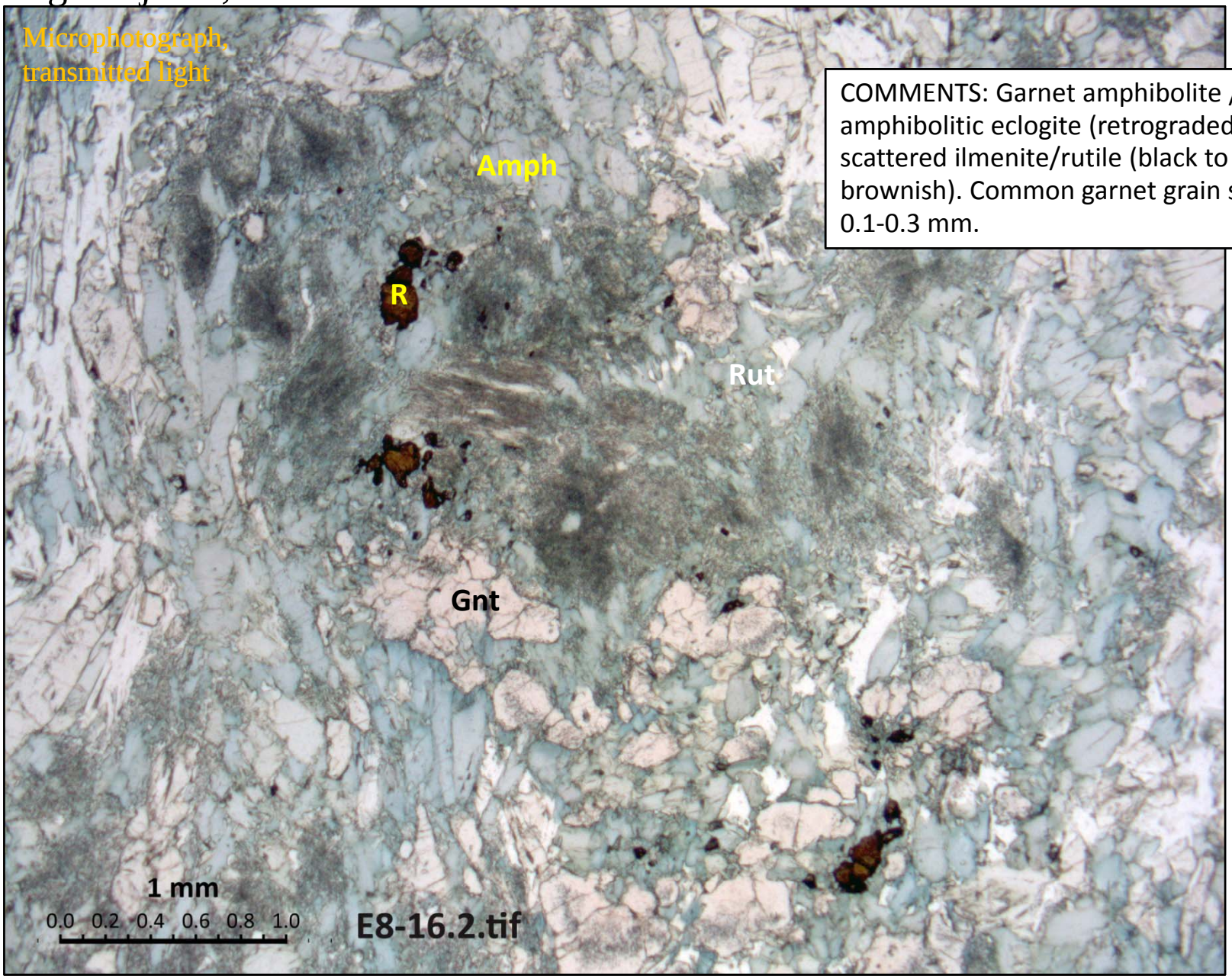
Thin-section overview picture, Dh8/16.2m

Comments

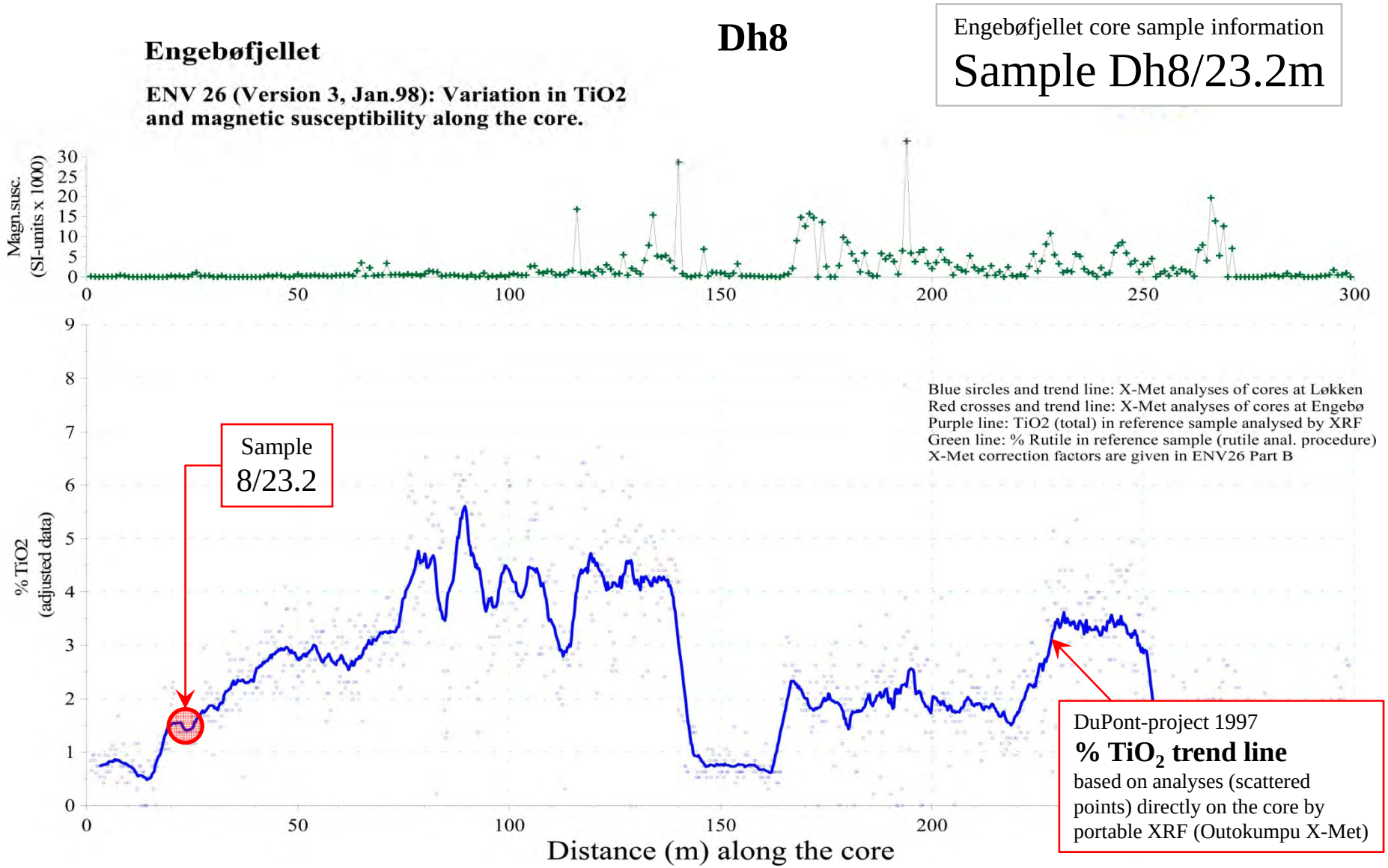
Amphibolitic eclogite



Engebøfjellet, Bh8/16.2m

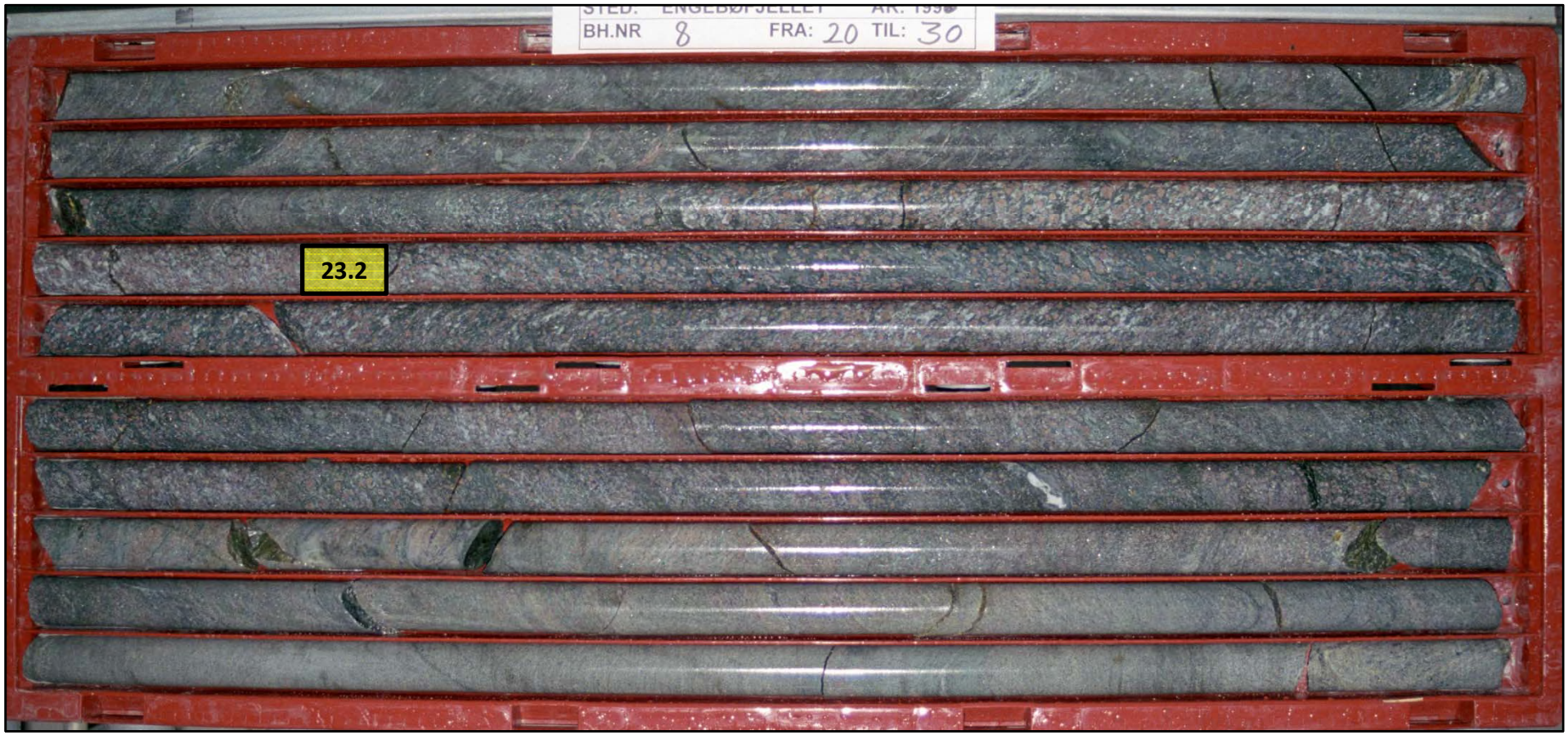


COMMENTS: Garnet amphibolite / amphibolitic eclogite (retrograded) with scattered ilmenite/rutile (black to dark brownish). Common garnet grain size is 0.1-0.3 mm.

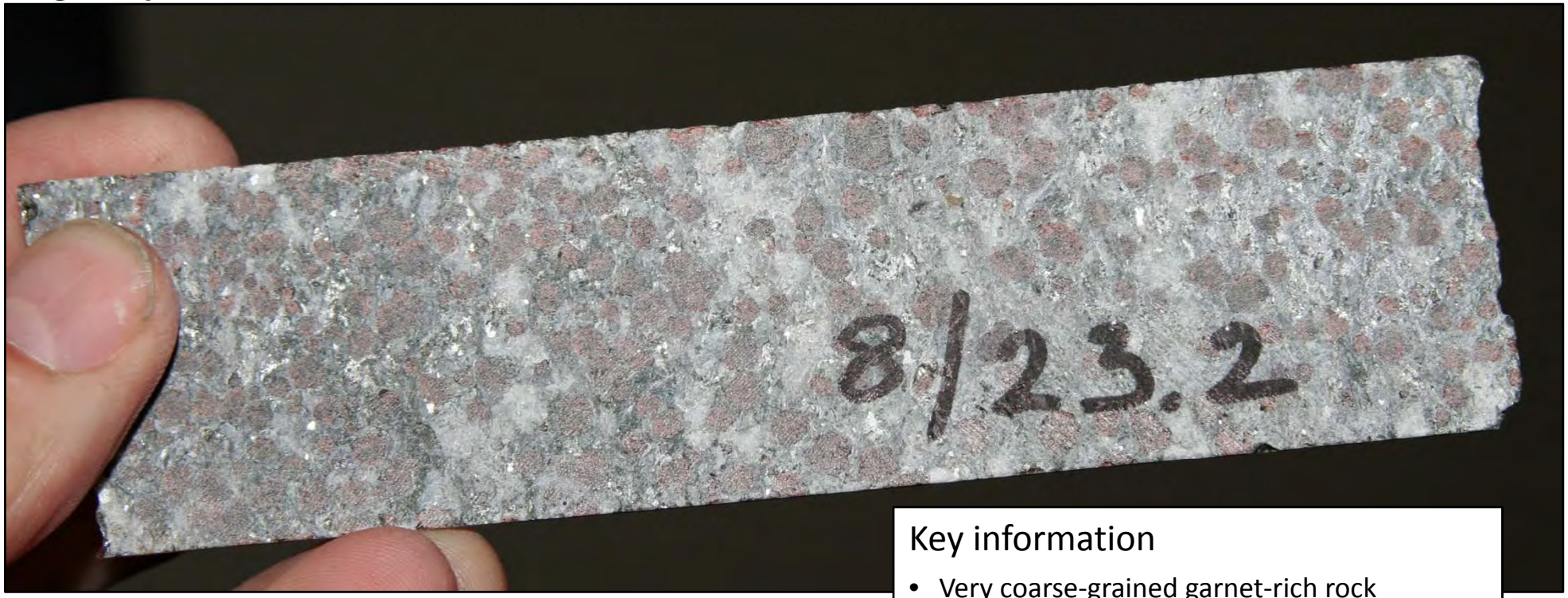

Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2
and magnetic susceptibility along the core.
Dh8
Engebøfjellet core sample information
Sample Dh8/23.2m
Magn.susc.
(SI-units x 1000)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
% TiO2
(adjusted data)
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
Distance (m) along the core
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Sample
8/23.2
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- The core section is heterogeneous with overall low TiO_2-content; a large portion of the section is coarse-grained garnet-rich rock such as sample 8/23.2.



Engebøfjellet, Bh8/23.2m



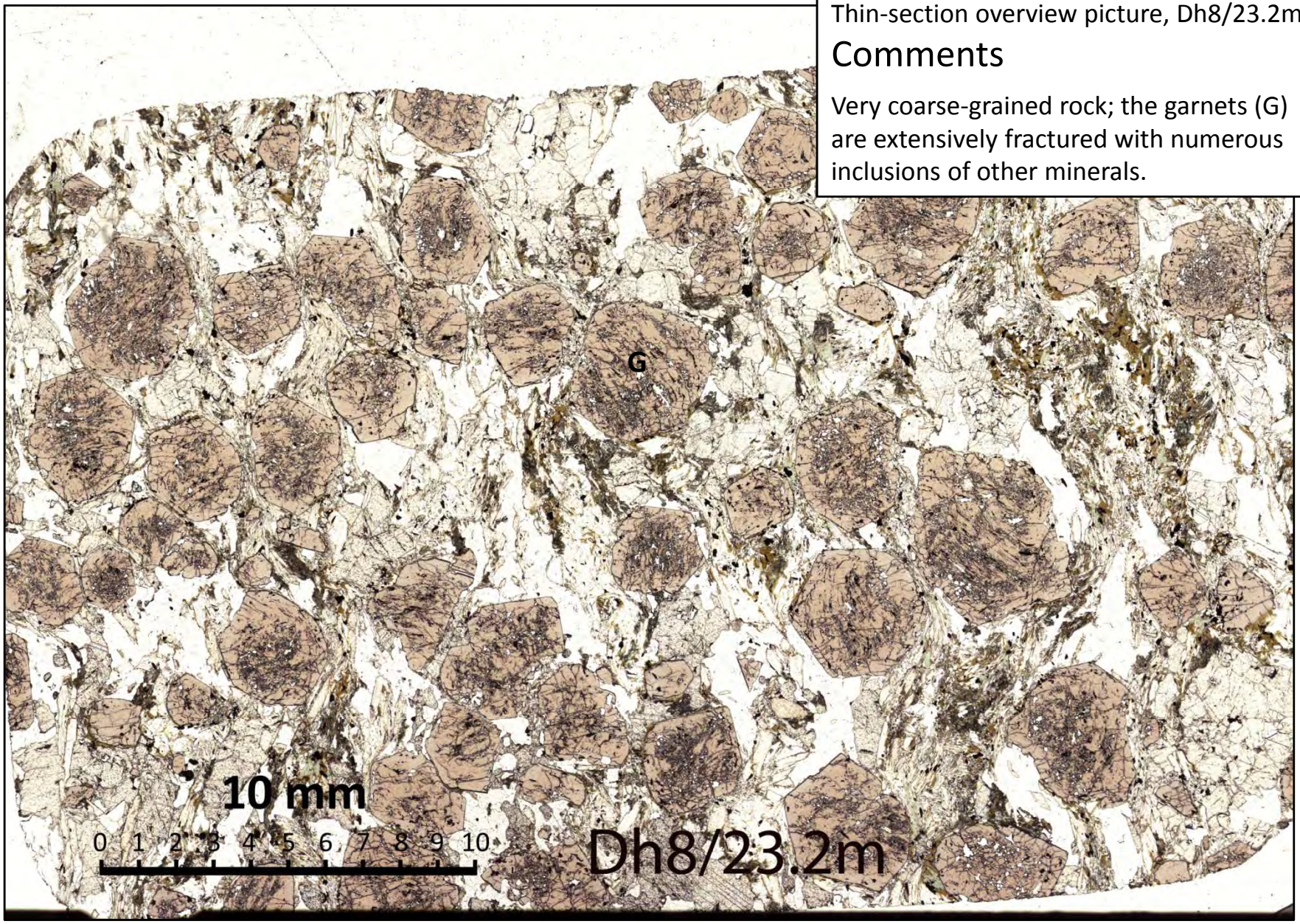
Key information

- Very coarse-grained garnet-rich rock
- Magnetic susceptibility: 0.00063 (SI-units)
- Specific gravity: 3.15 g/cm^3
- 0.5 % TiO_2 , 9.8 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

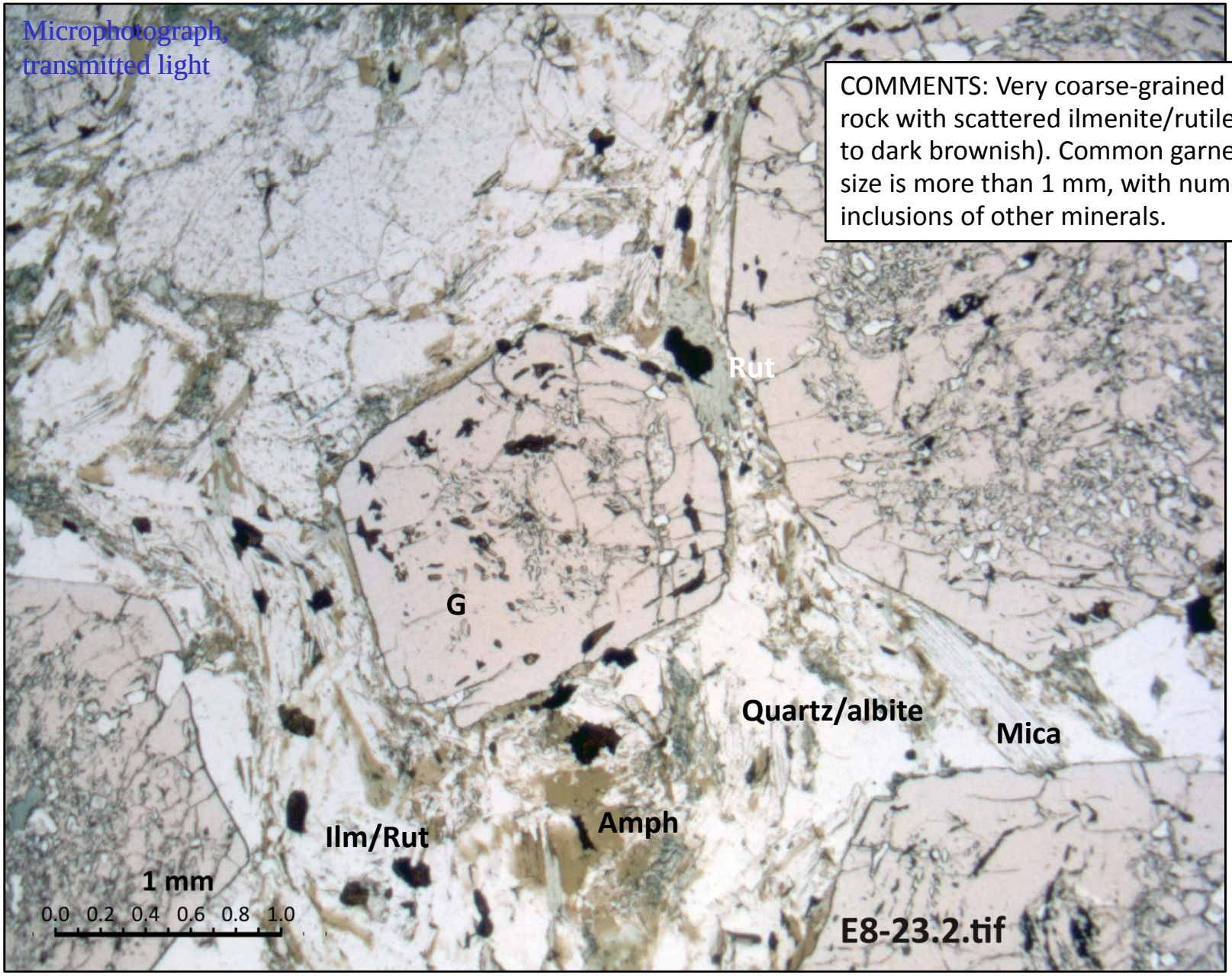
Thin-section overview picture, Dh8/23.2m

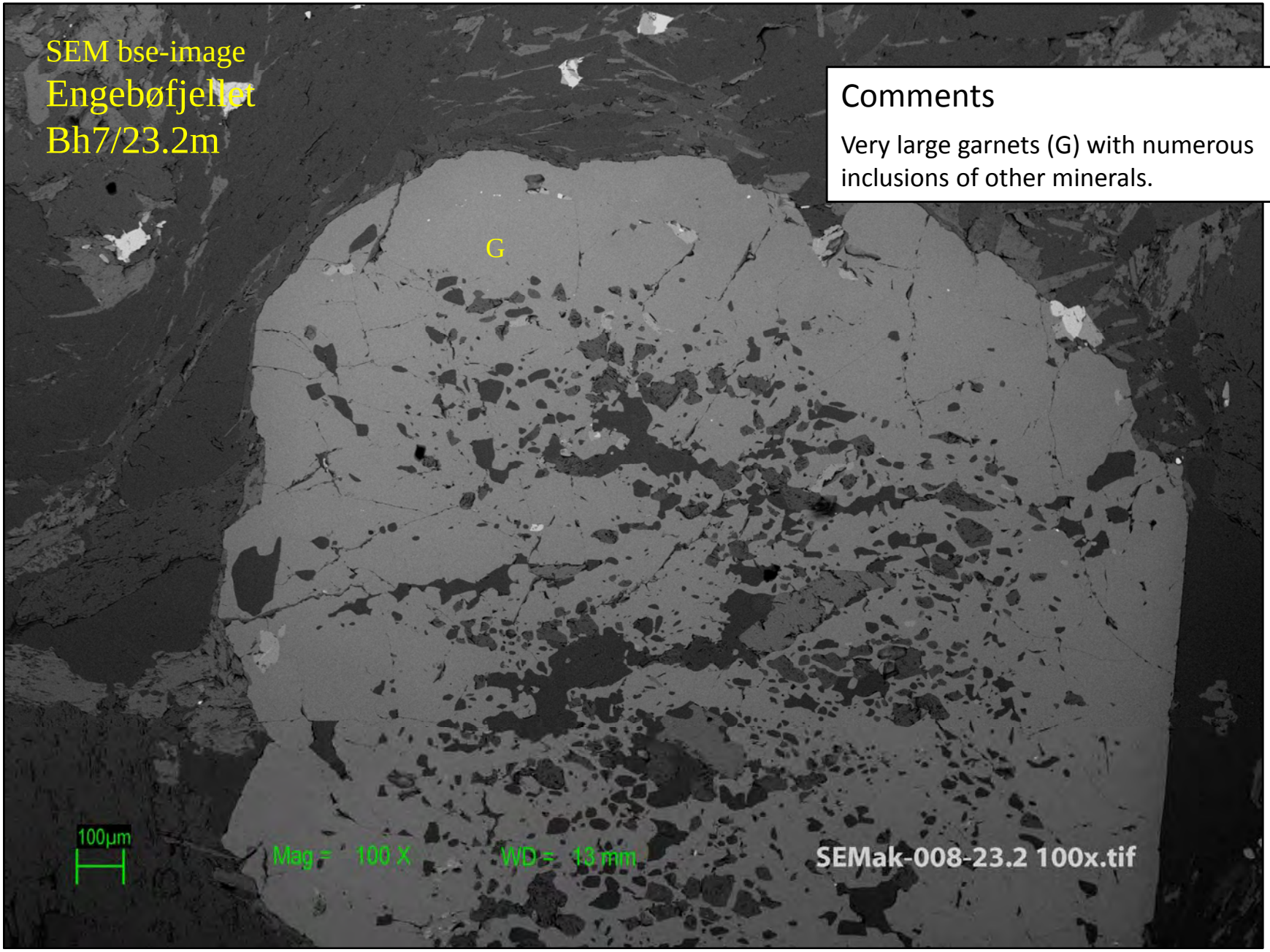
Comments

Very coarse-grained rock; the garnets (G) are extensively fractured with numerous inclusions of other minerals.



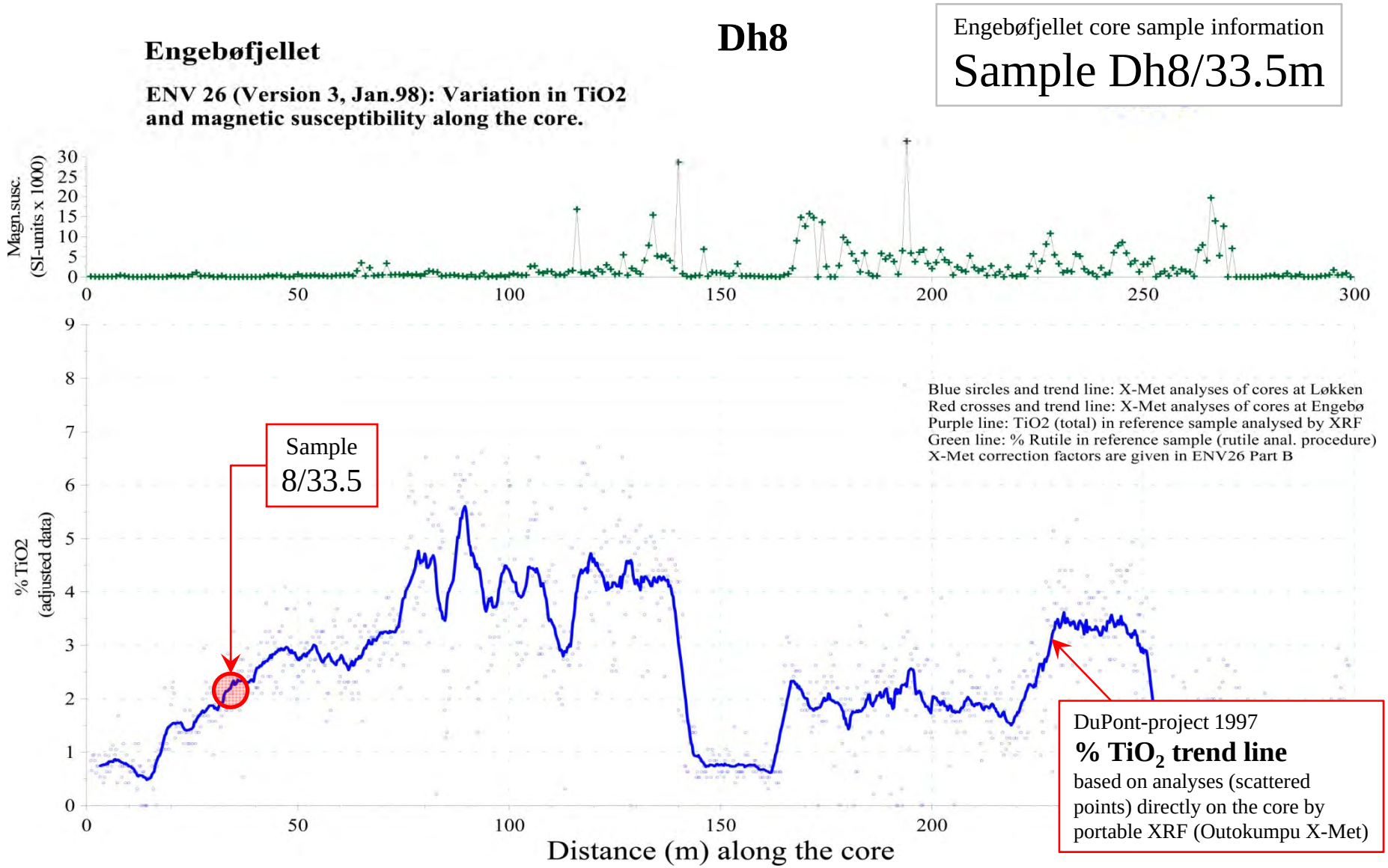
Engebøfjellet, Bh8/23.2m





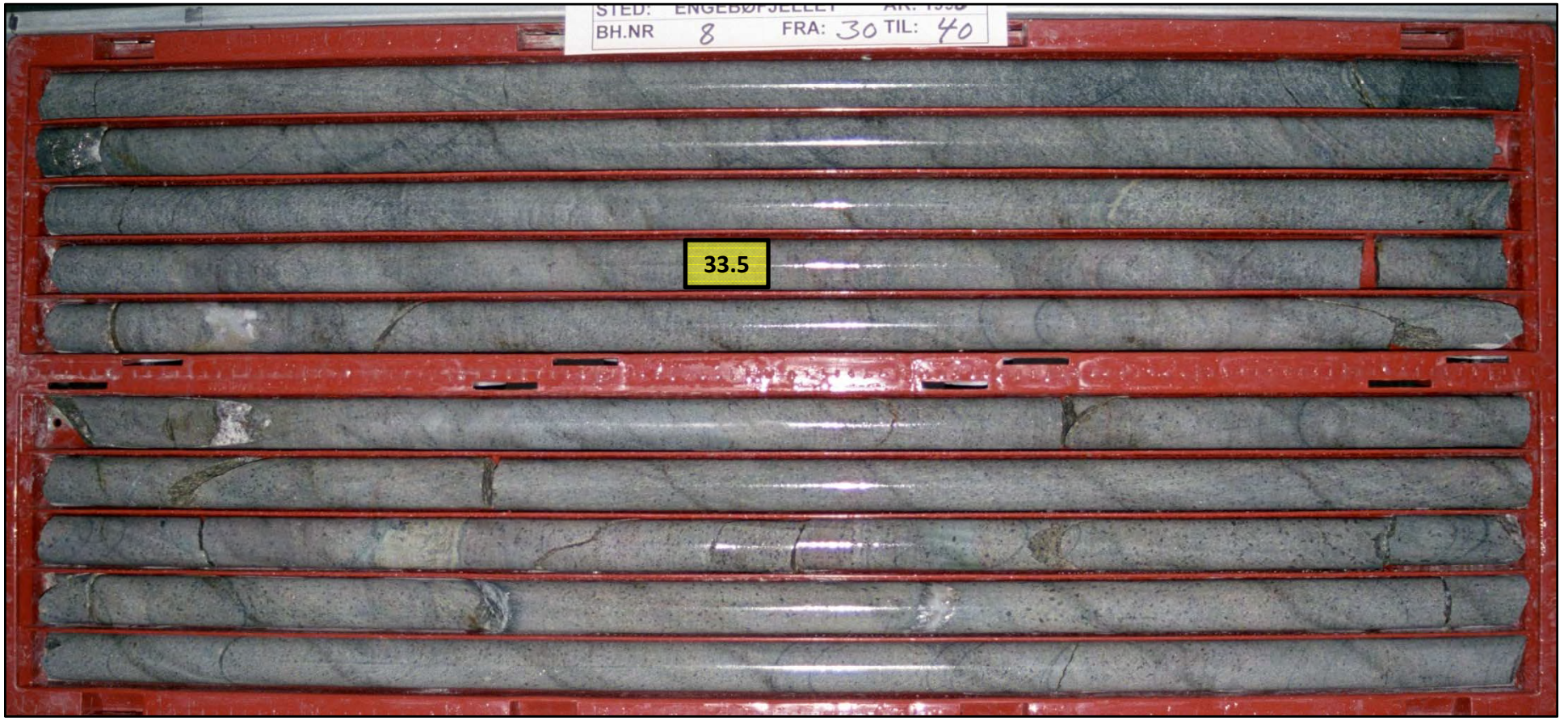
Comments

Very large garnets (G) with numerous inclusions of other minerals.


Engebøfjellet
Dh8
ENV 26 (Version 3, Jan.98): Variation in TiO2
and magnetic susceptibility along the core.
Engebøfjellet core sample information
Sample Dh8/33.5m
Magn.susc.
(SI-units x 1000)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
9
8
7
6
5
4
3
2
1
0
% TiO2
(adjusted data)
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Sample
8/33.5
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)
0
50
100
150
200
Distance (m) along the core

Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Massive eclogite with amphibole porphyroblasts; minor retrograde alteration.



Engebøfjellet, Bh8/33.5m

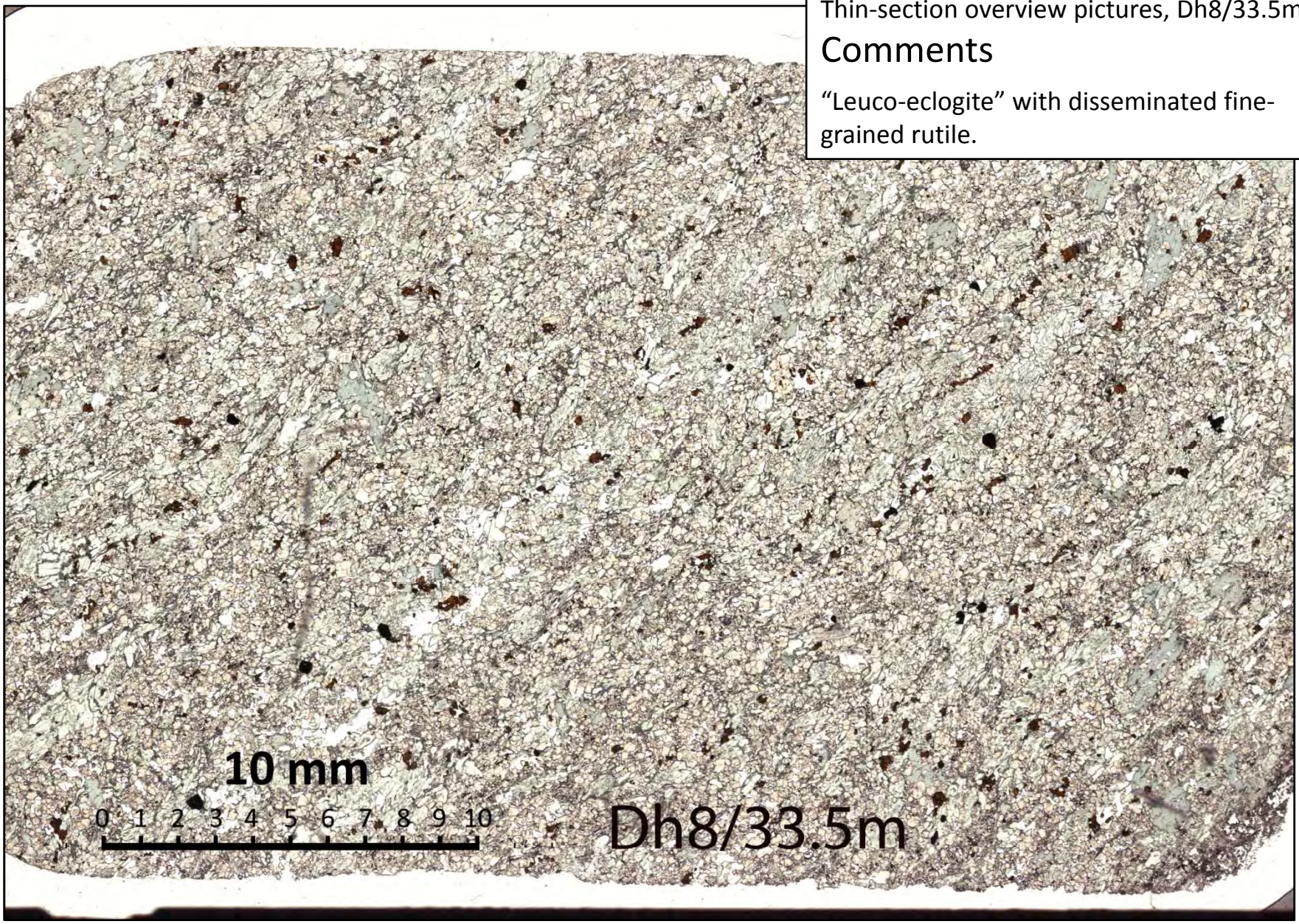
Key information

- Omphacite-rich eclogite with large amphibole porphyroblasts (dark green patches).
- Magnetic susceptibility: 0.00087 (SI-units)
- Specific gravity: 3.42 g/cm^3
- 1.1 % TiO_2 , 13.5 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

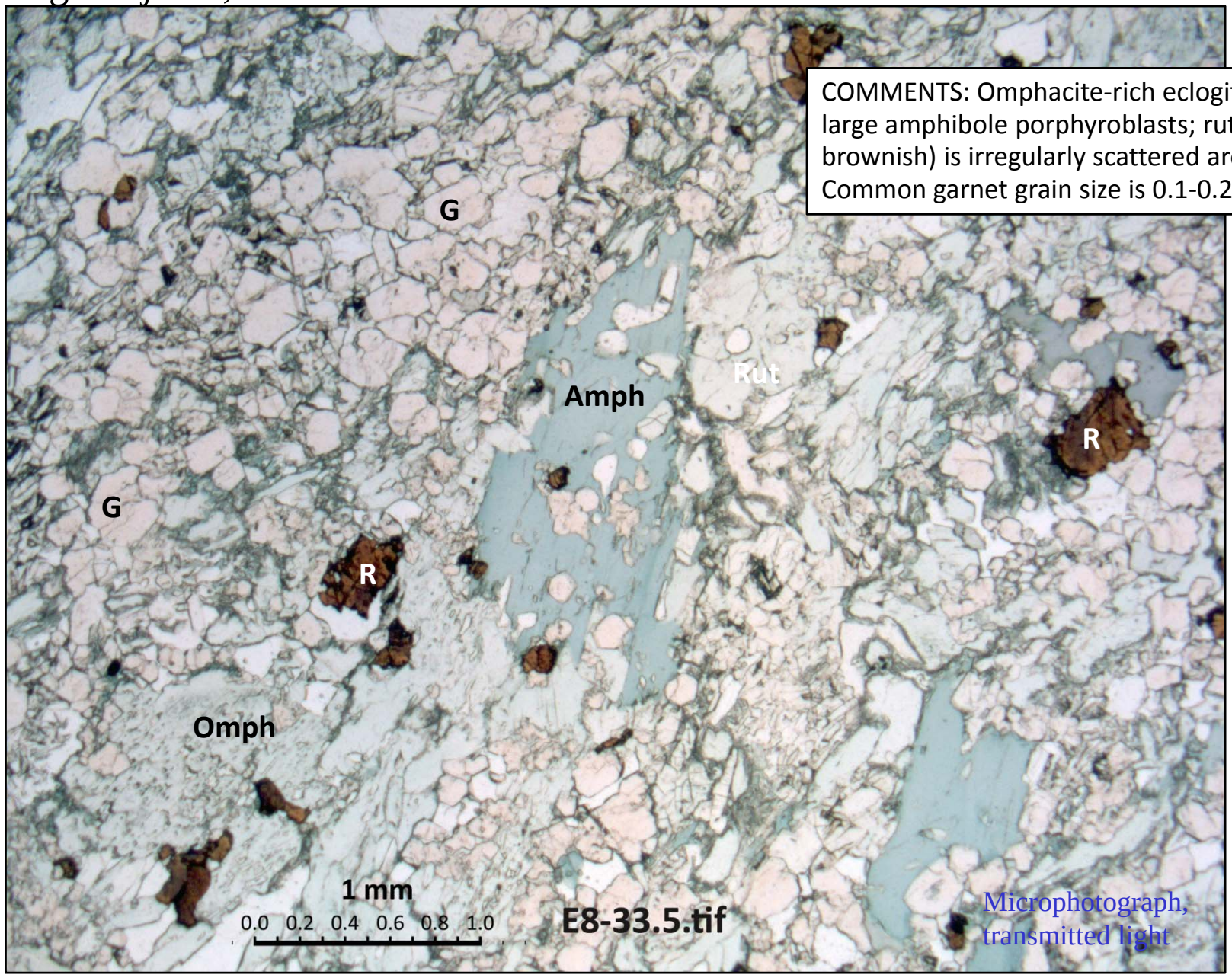
Thin-section overview pictures, Dh8/33.5m

Comments

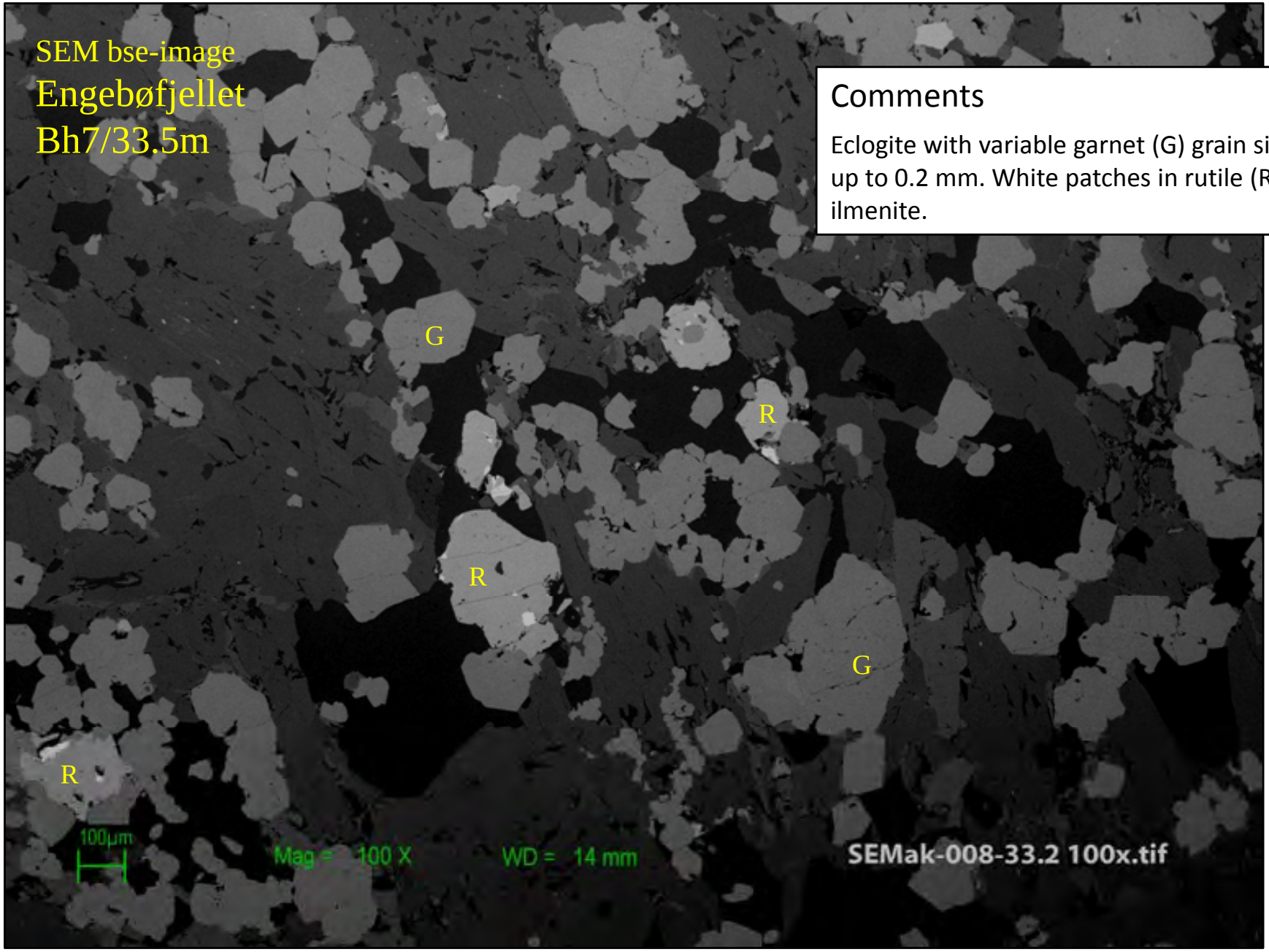
"Leuco-eclogite" with disseminated fine-grained rutile.



Engebøfjellet, Bh8/33.5m

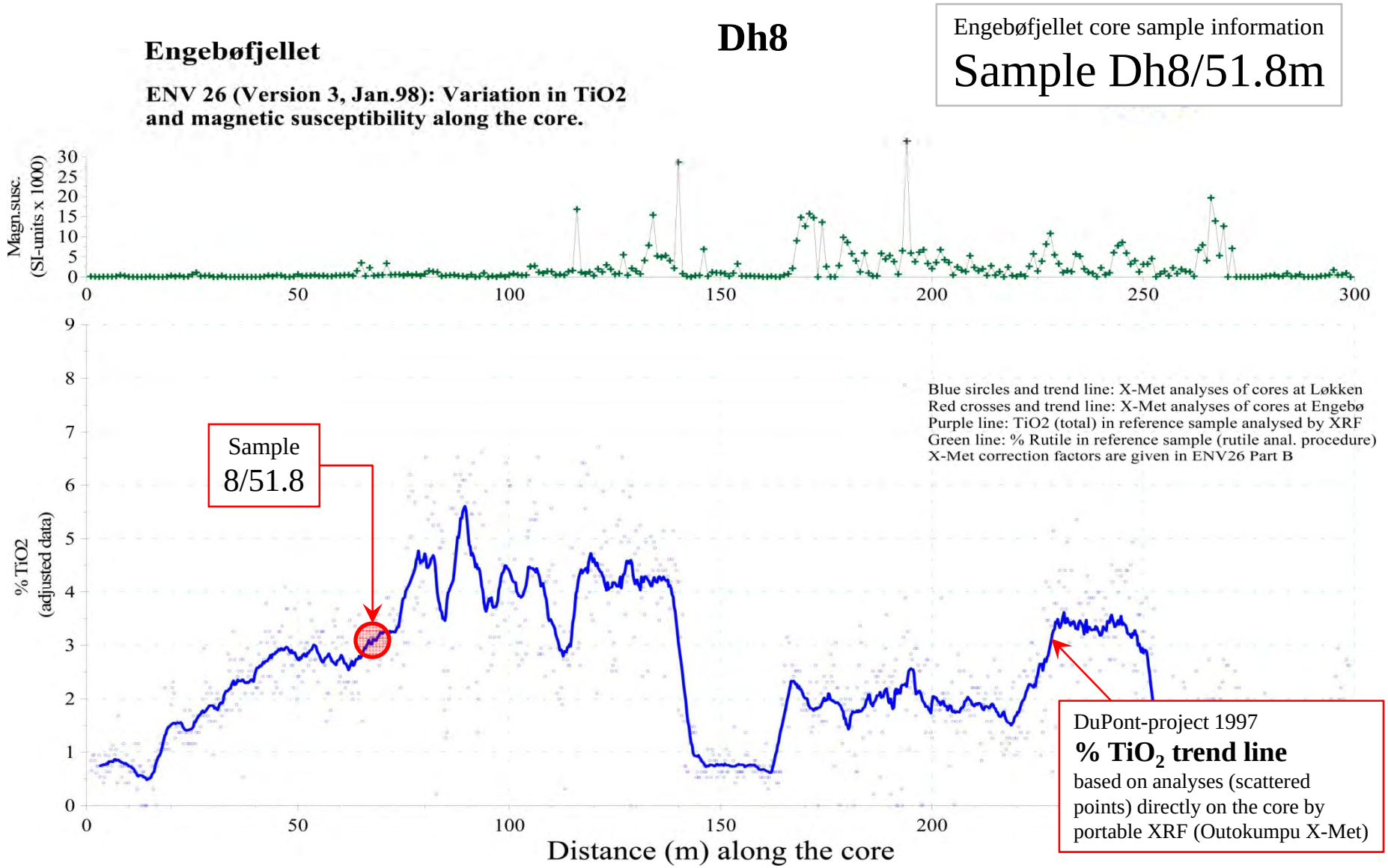


COMMENTS: Omphacite-rich eclogite with large amphibole porphyroblasts; rutile (dark brownish) is irregularly scattered around. Common garnet grain size is 0.1-0.2 mm.



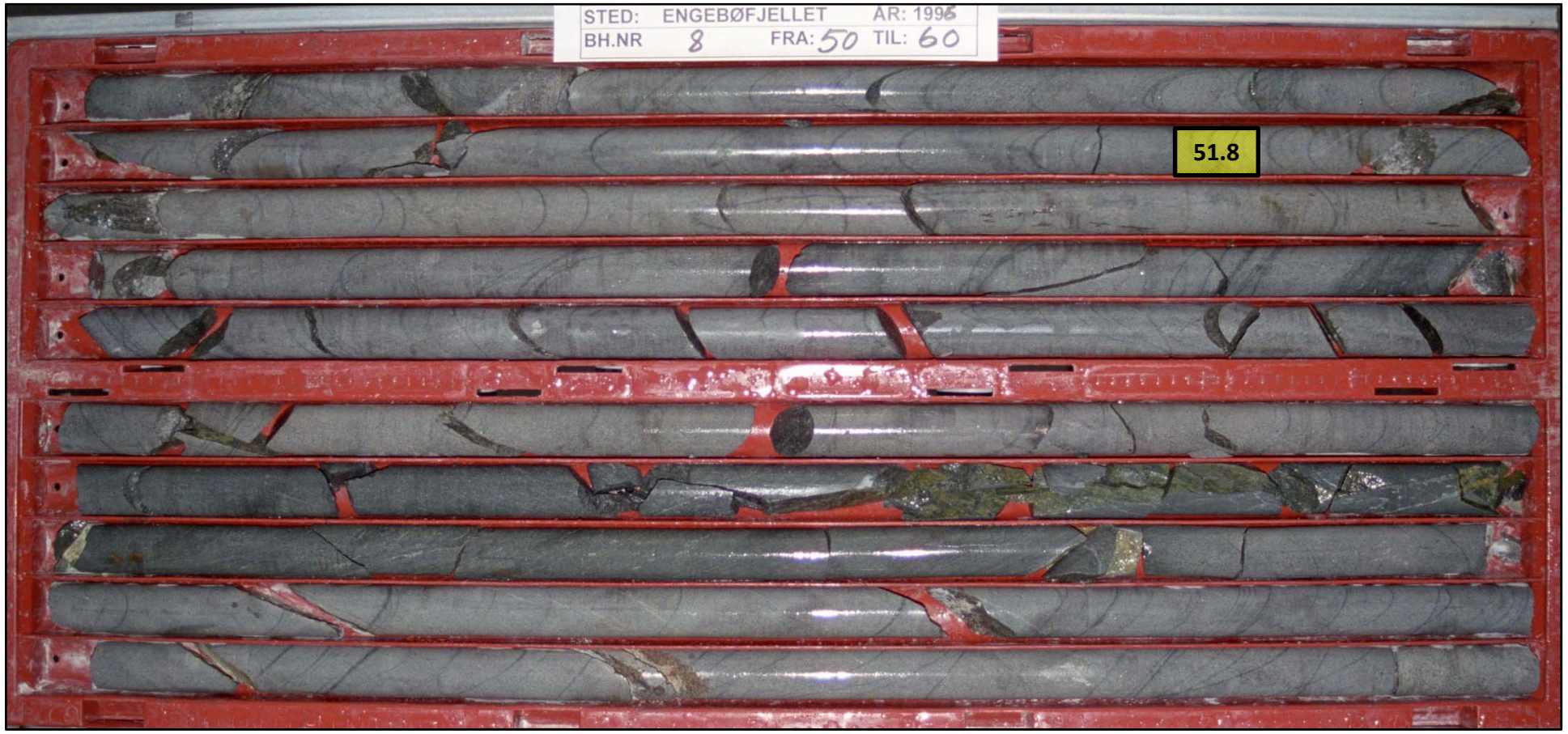
Comments

Eclogite with variable garnet (G) grain size up to 0.2 mm. White patches in rutile (R) is ilmenite.

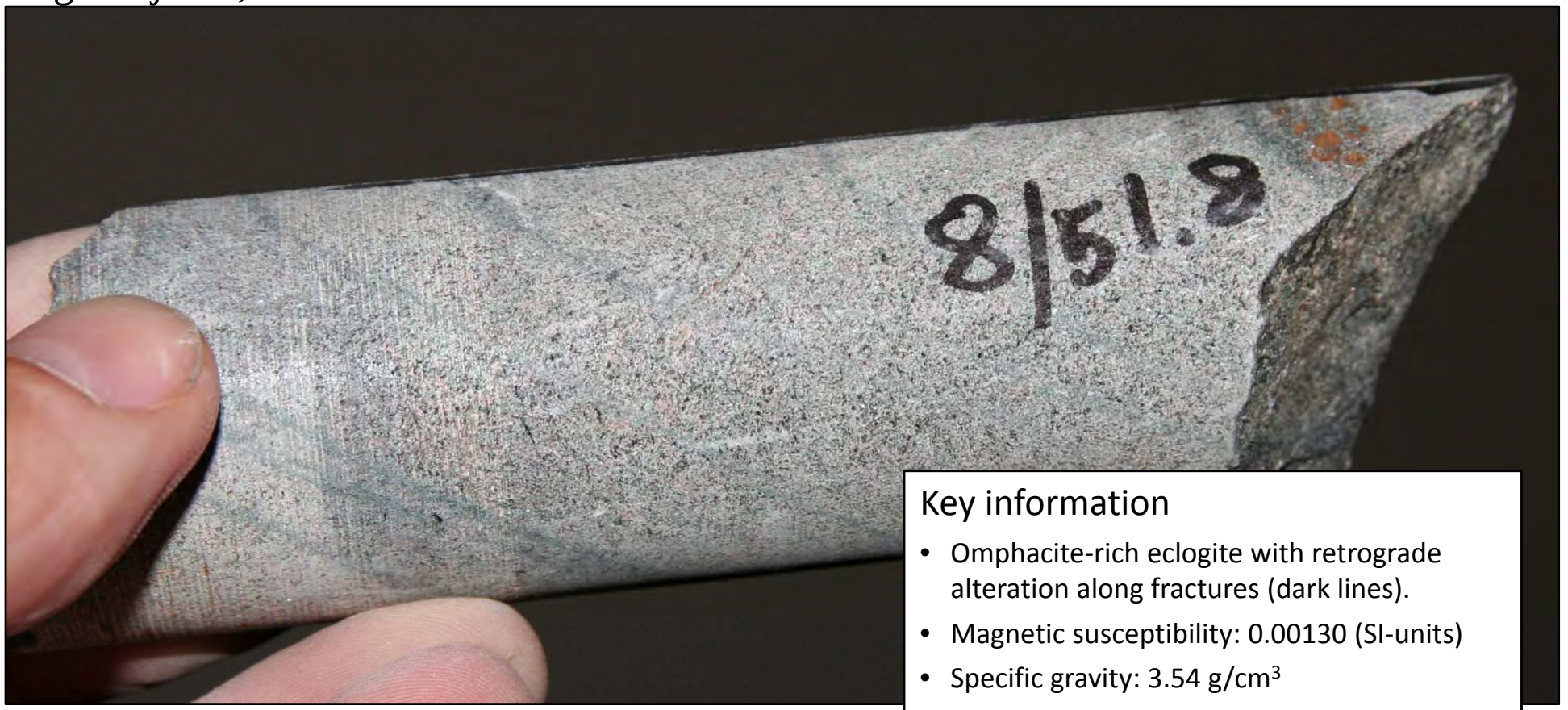

Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2
and magnetic susceptibility along the core.
Dh8
Engebøfjellet core sample information
Sample Dh8/51.8m
Magn.susc.
(SI-units x 1000)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
% TiO2
(adjusted data)
0
1
2
3
4
5
6
7
8
9
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Sample
8/51.8
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)
Distance (m) along the core

Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Massive eclogite with distinct retrograde alteration along fractures as well as diffusely retrograded in dark parts of the core.



Engebøfjellet, Bh8/51.8m



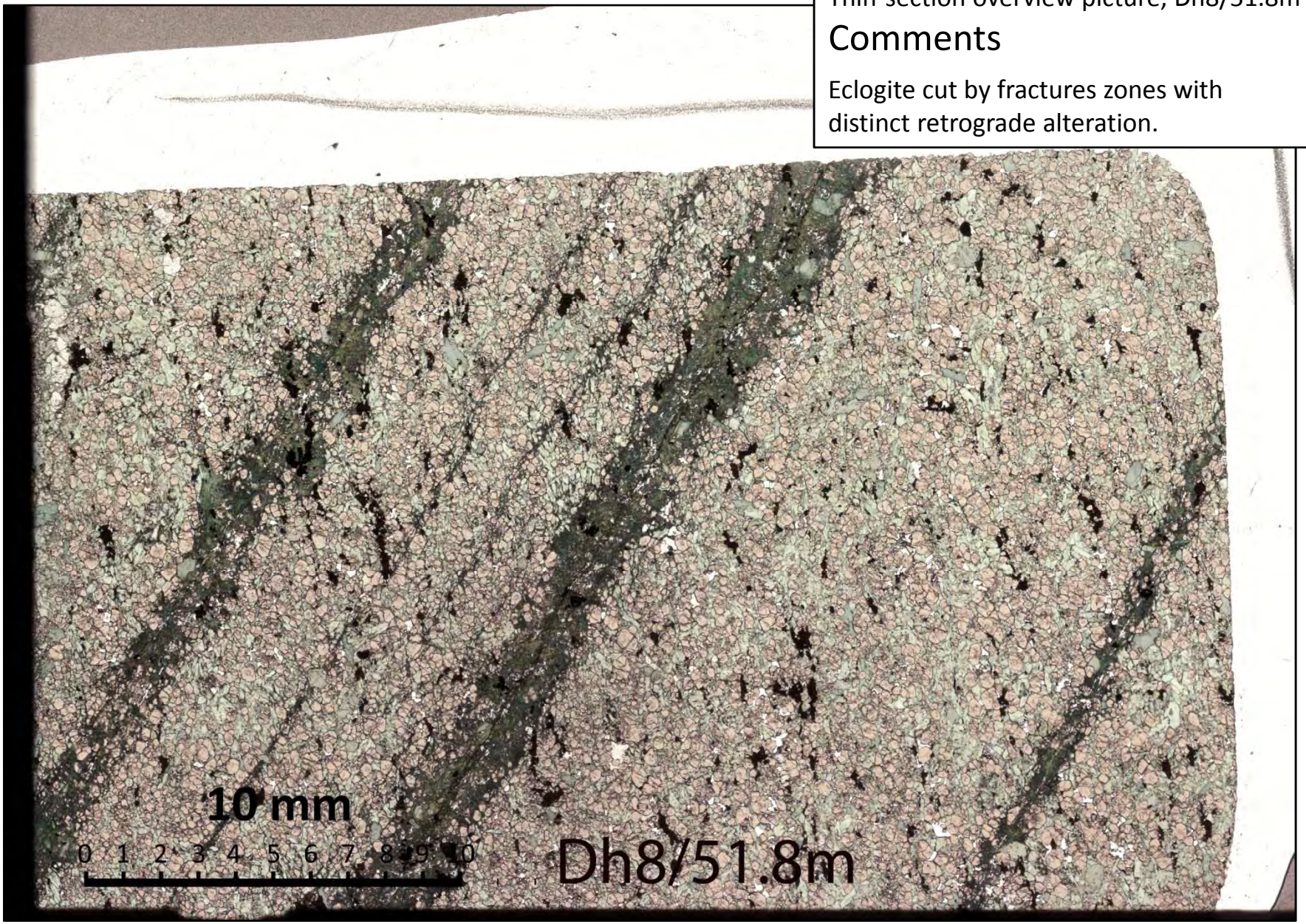
Key information

- Omphacite-rich eclogite with retrograde alteration along fractures (dark lines).
- Magnetic susceptibility: 0.00130 (SI-units)
- Specific gravity: 3.54 g/cm^3
- 1.3 % TiO_2 , 17.3 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

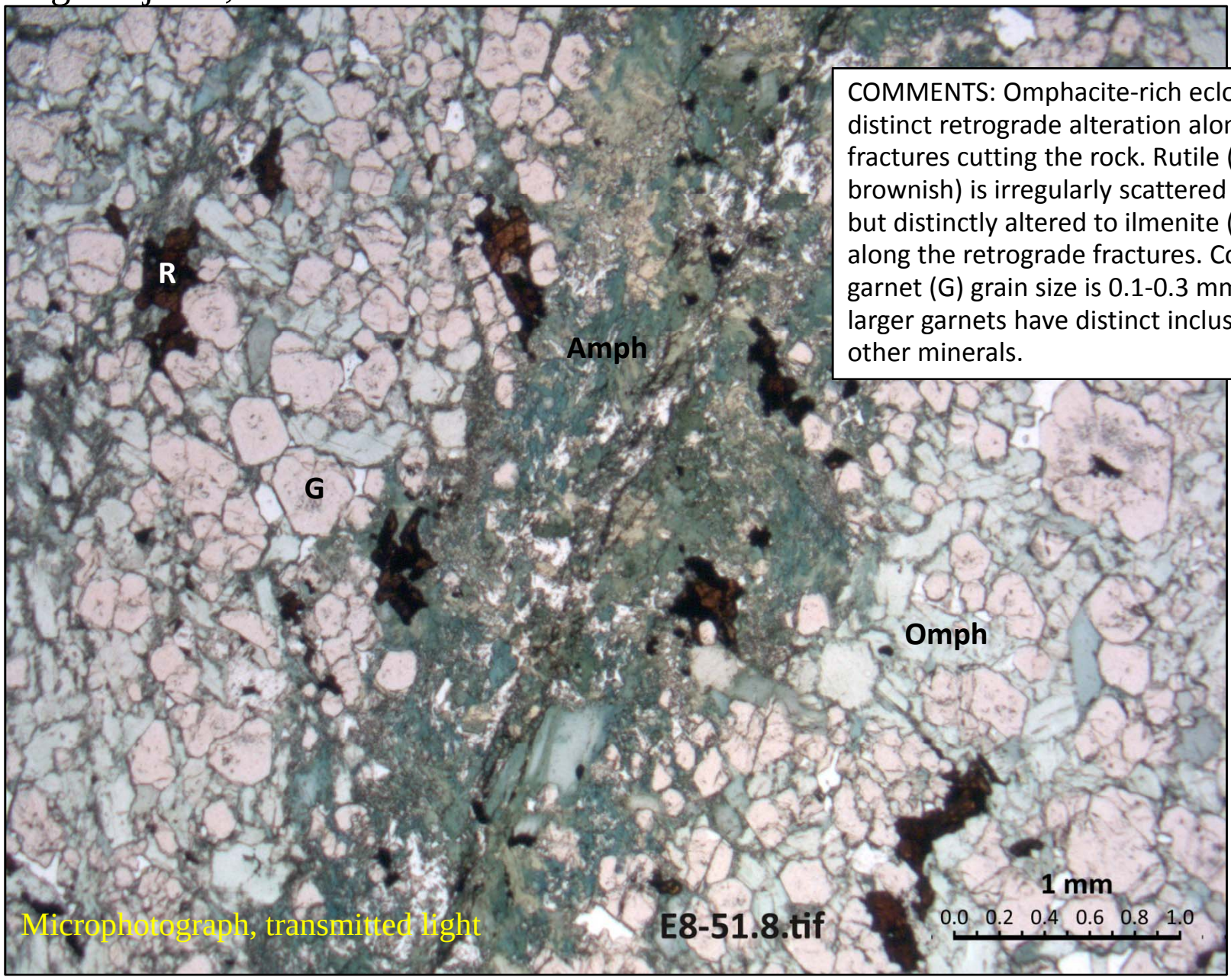
Thin-section overview picture, Dh8/51.8m

Comments

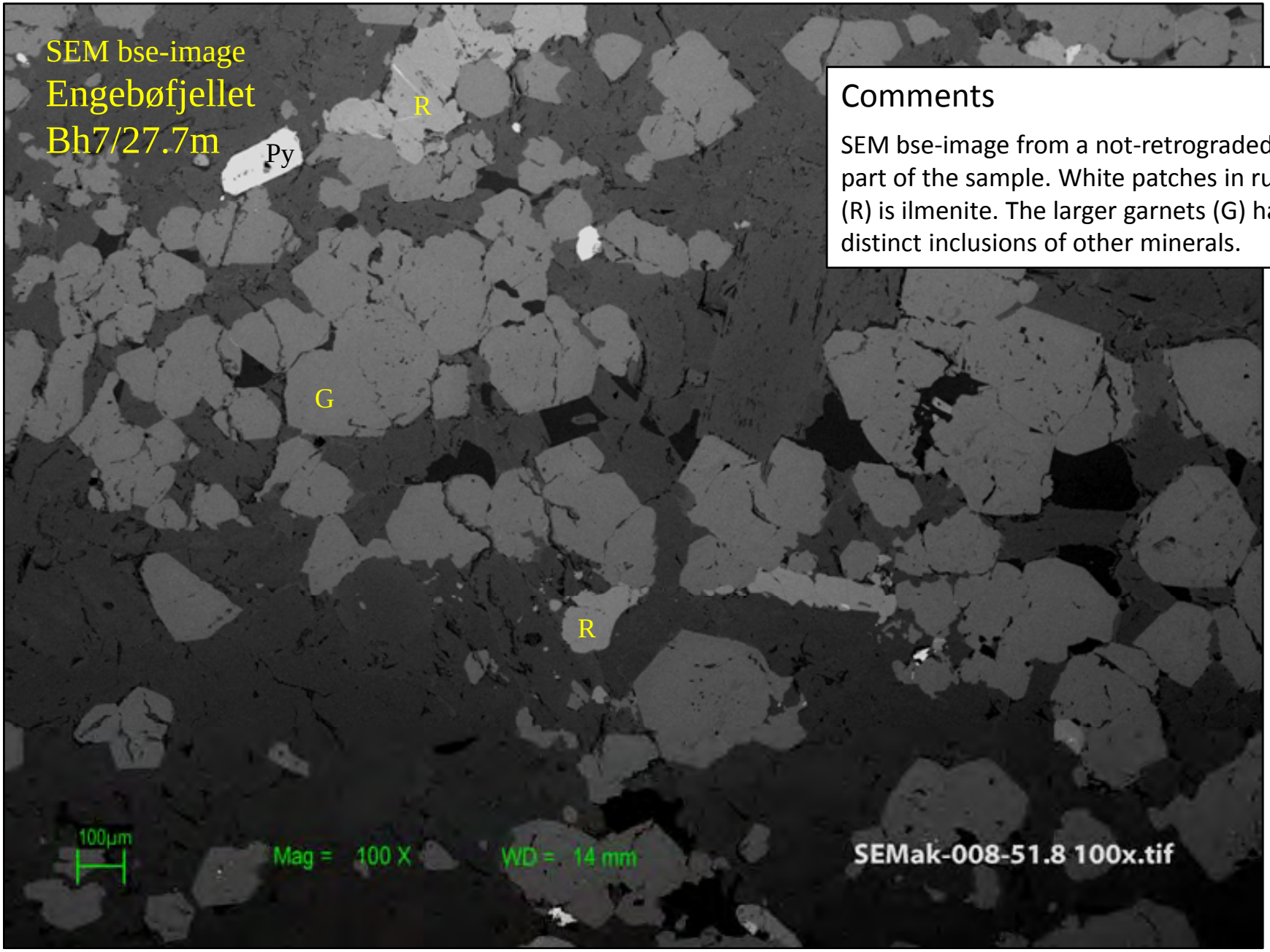
Eclogite cut by fractures zones with distinct retrograde alteration.



Engebøfjellet, Bh8/51.8m

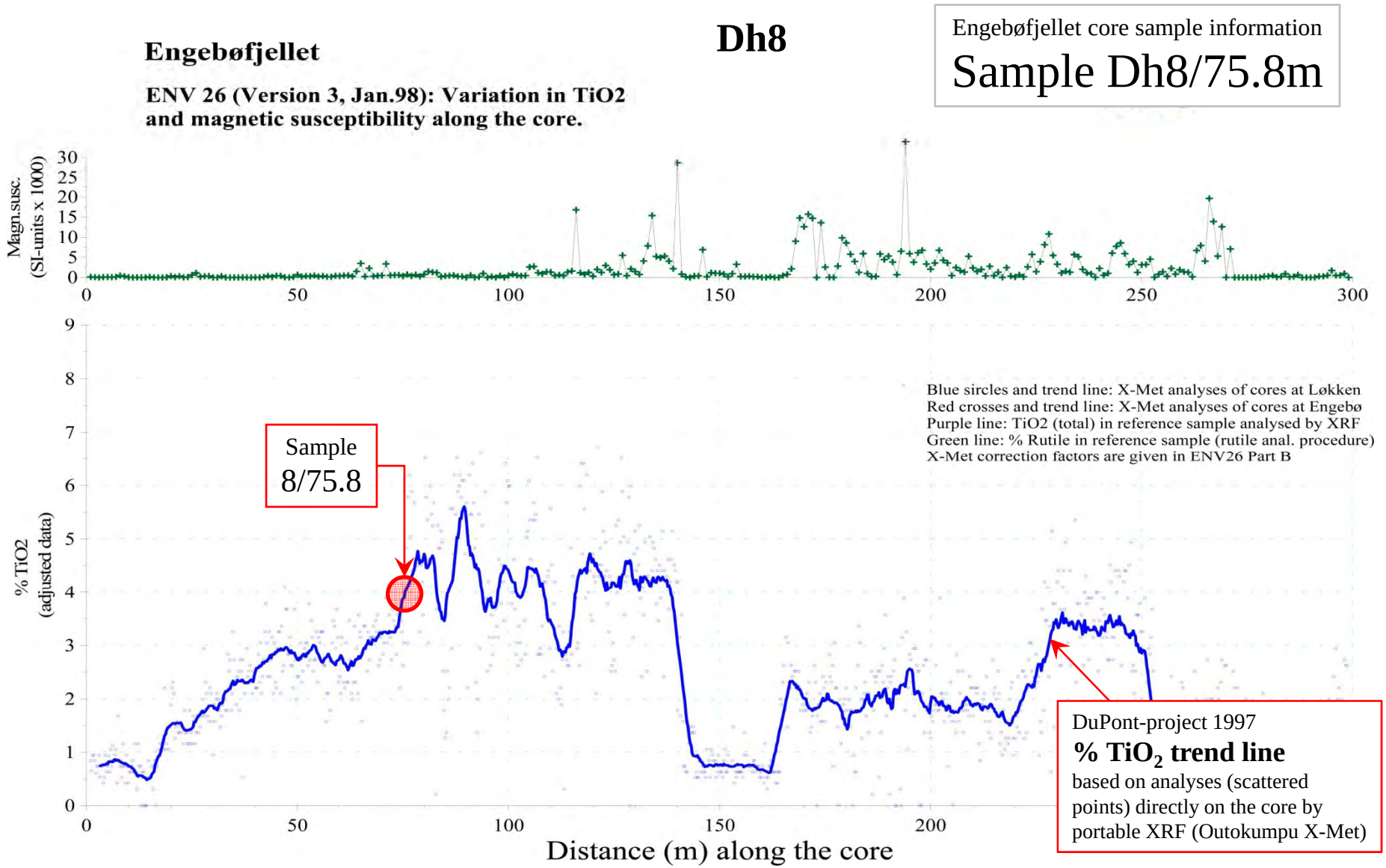


COMMENTS: Omphacite-rich eclogite with distinct retrograde alteration along fractures cutting the rock. Rutile (R, dark brownish) is irregularly scattered around, but distinctly altered to ilmenite (black) along the retrograde fractures. Common garnet (G) grain size is 0.1-0.3 mm. The larger garnets have distinct inclusions of other minerals.



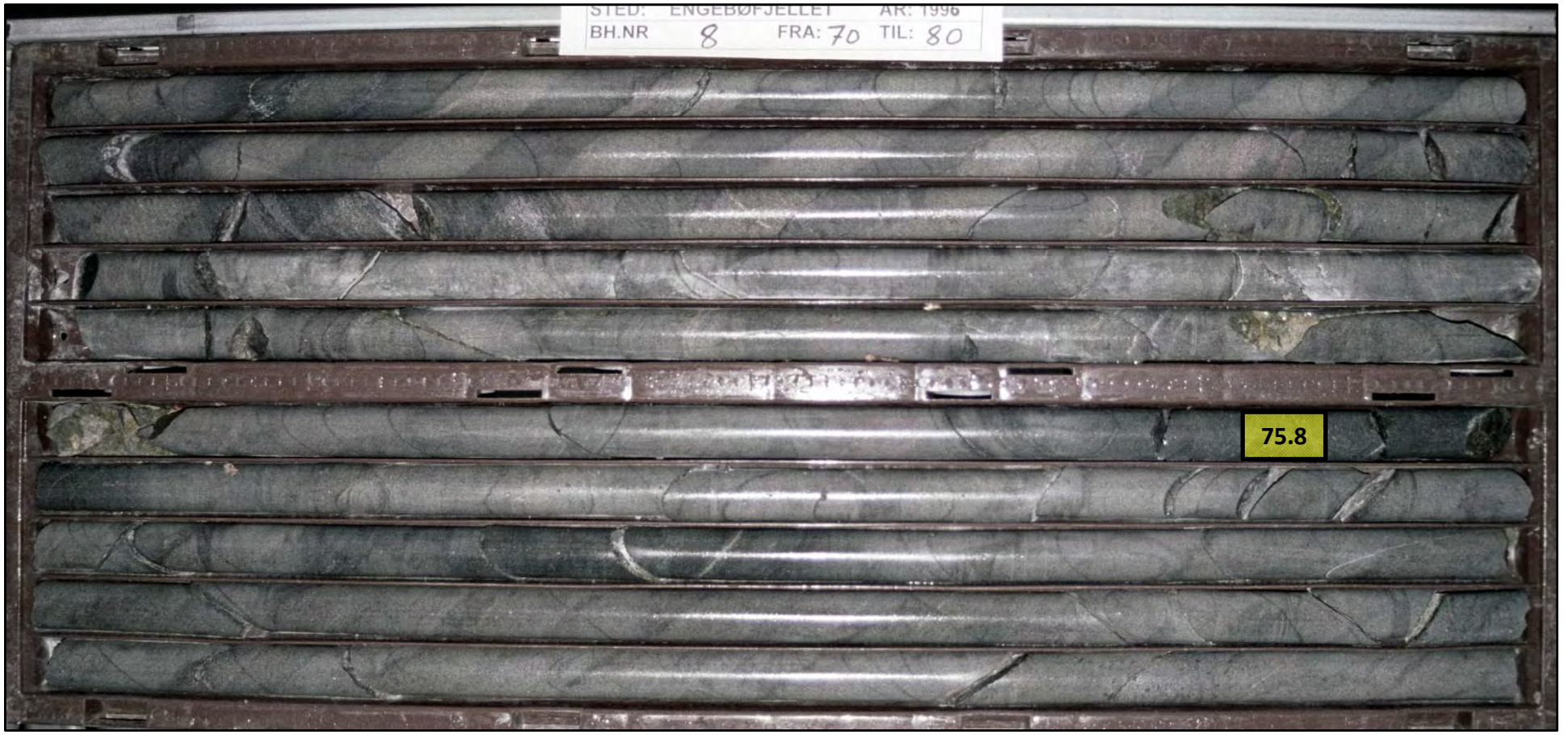
Comments

SEM bse-image from a not-retrograded part of the sample. White patches in rutile (R) is ilmenite. The larger garnets (G) have distinct inclusions of other minerals.


Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2
and magnetic susceptibility along the core.
Dh8
Engebøfjellet core sample information
Sample Dh8/75.8m
Magn.susc.
(SI-units x 1000)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
% TiO2
(adjusted data)
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
Distance (m) along the core
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Sample
8/75.8
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Amphibolitic eclogite; extensively retrograded; probably representative for a large volume of rock in this part of the deposit.



Engebøfjellet, Bh8/75.8m

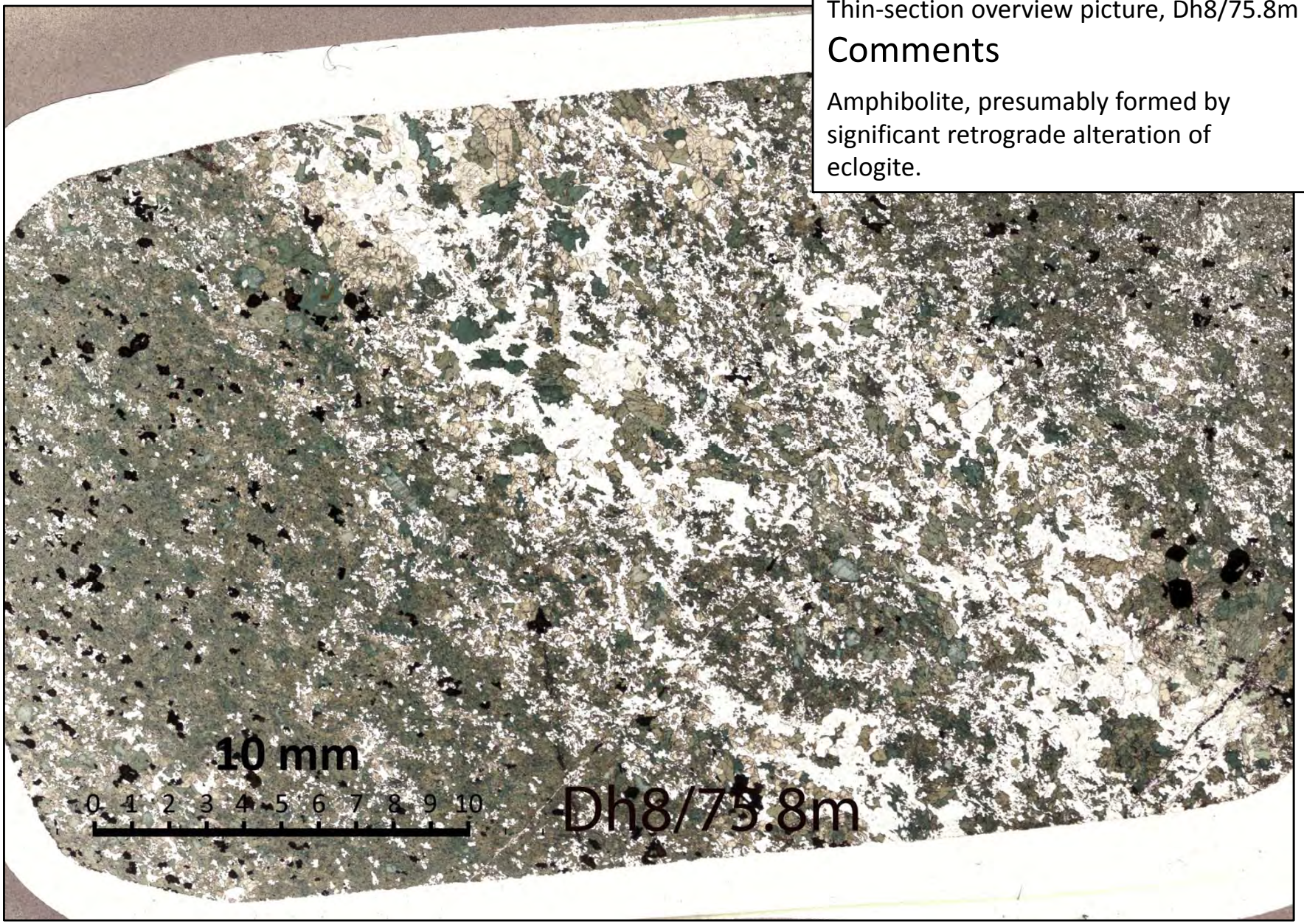
Key information

- Amphibolite; probably formed by retrograde alteration of eclogite; low rutile/ilmenite-ratio (large $TiO_{2\ ilmenite}$ portion); moderate magnetic susceptibility.
- Magnetic susceptibility: 0.00495 (SI-units)
- Specific gravity: 3.14 g/cm^3
- 1.8 % TiO_2 , 16.3 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

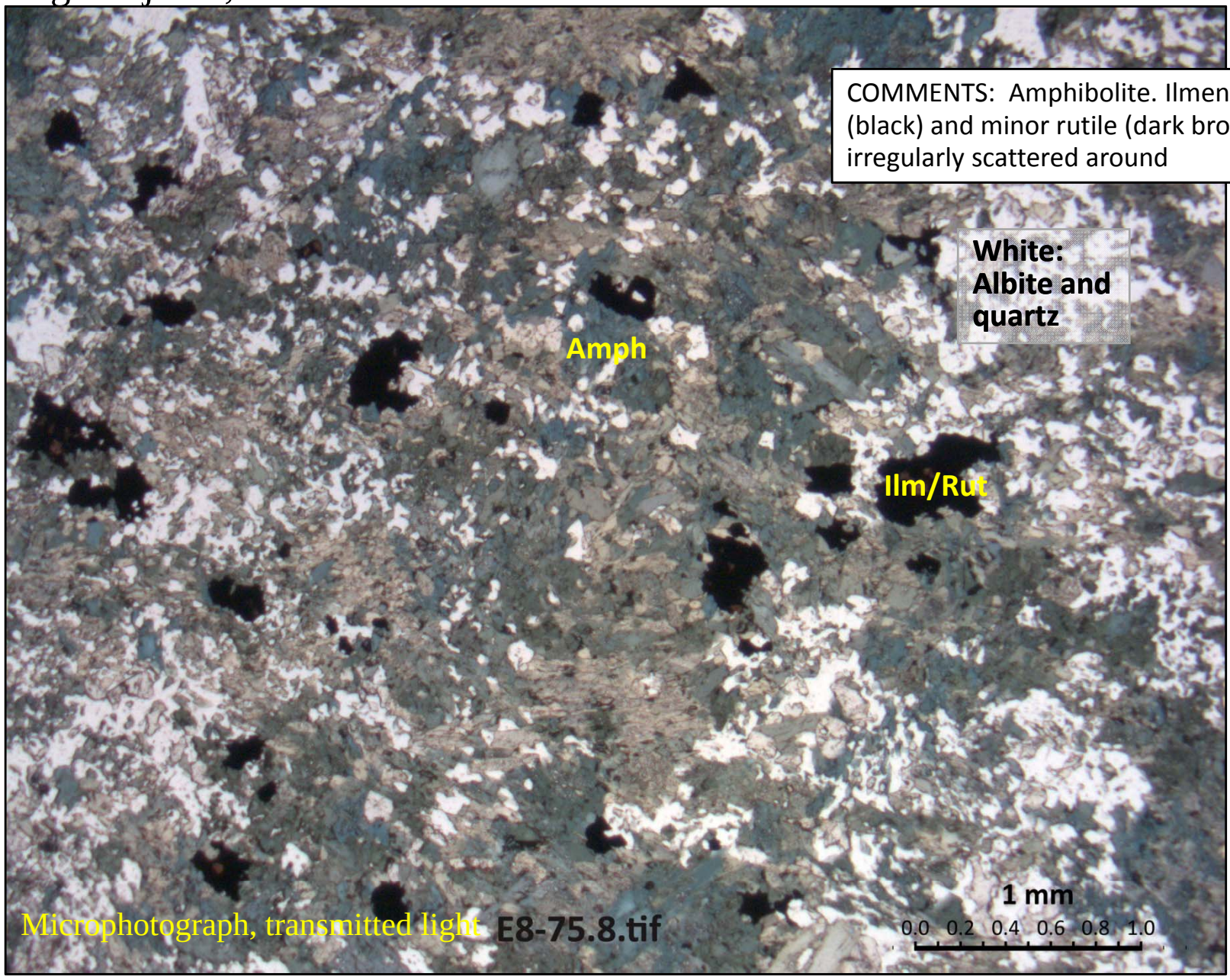
Thin-section overview picture, Dh8/75.8m

Comments

Amphibolite, presumably formed by significant retrograde alteration of eclogite.



Engebøfjellet, Bh8/75.8m



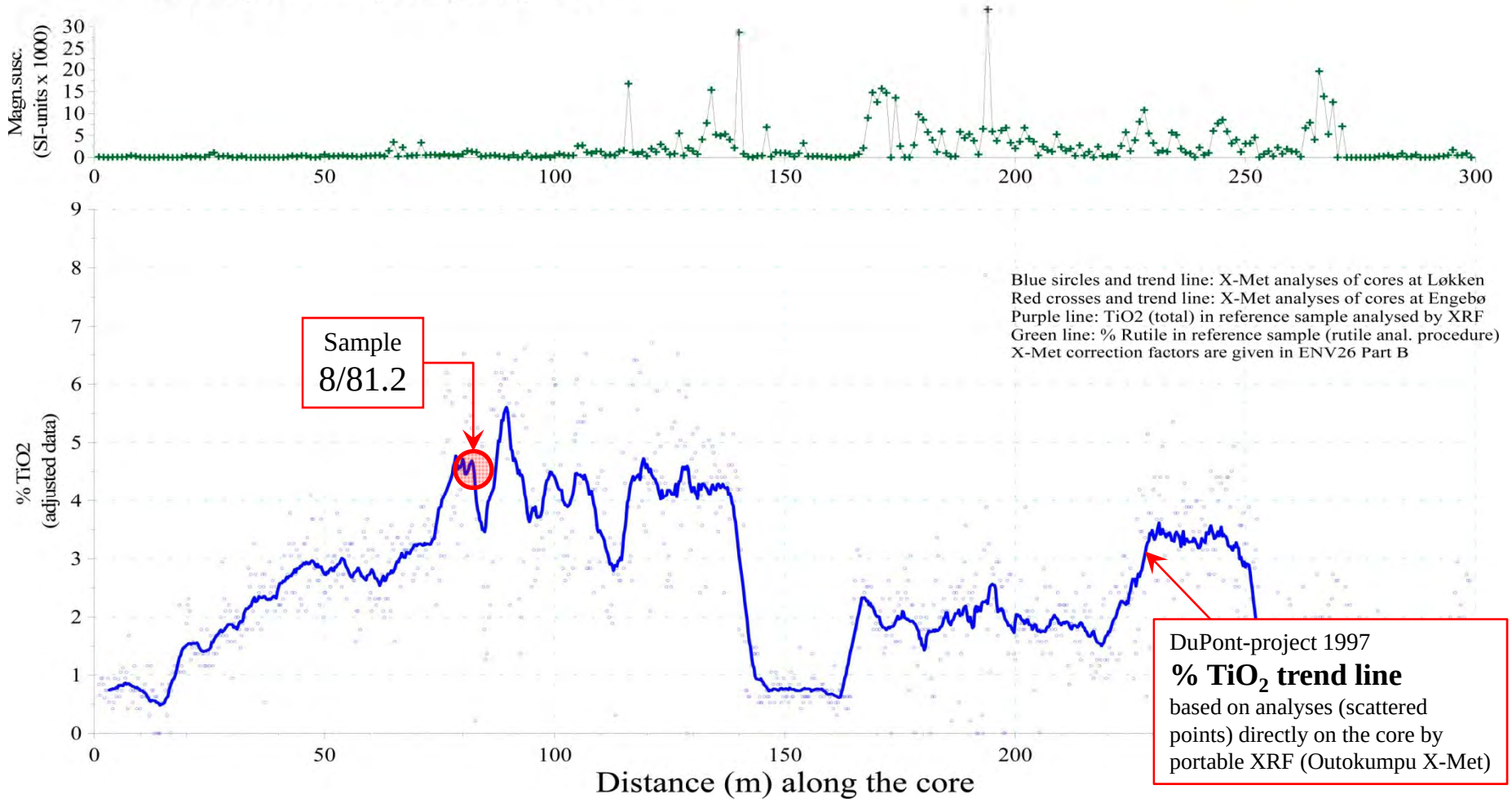
Engebøfjellet core sample information

Sample Dh8/81.2m

Engebøfjellet

ENV 26 (Version 3, Jan.98): Variation in TiO2 and magnetic susceptibility along the core.

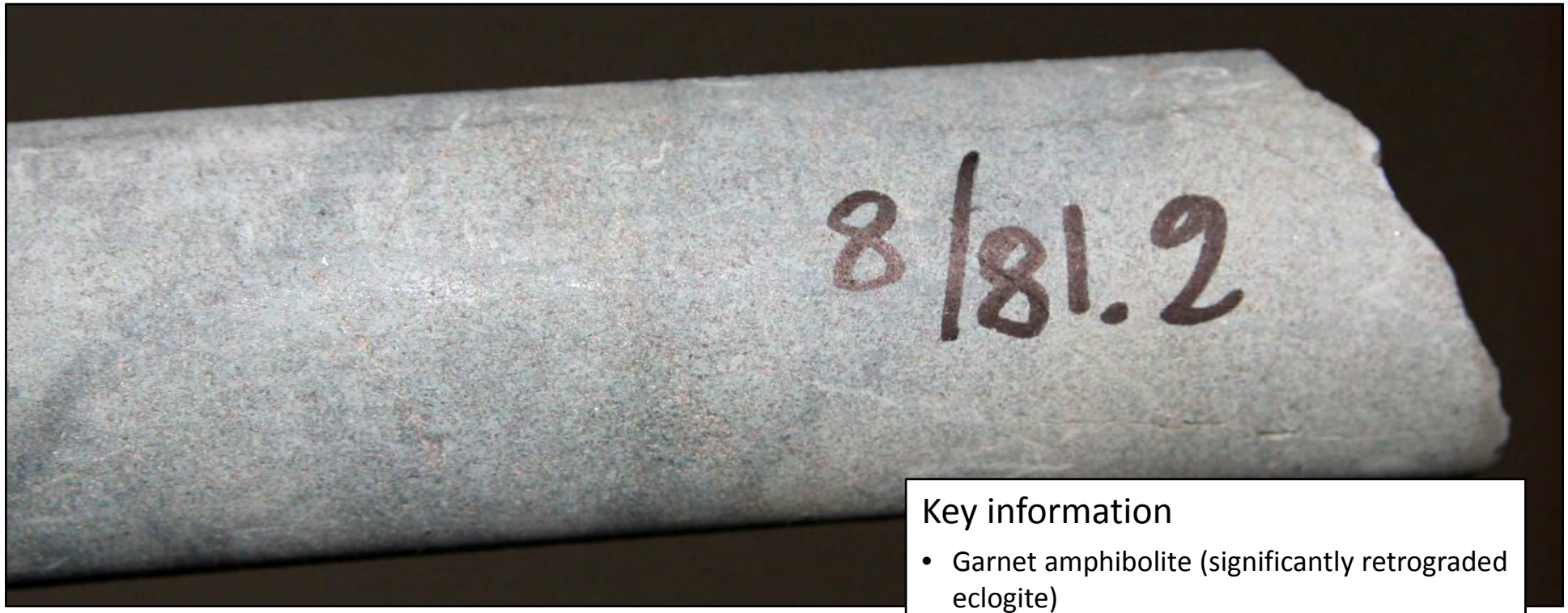
Dh8



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Amphibolitic eclogite; extensively retrograded; presumably representative for a large portion of eclogite in this part of the deposit. In this case retrograde alteration is not associated with particularly high magnetic susceptibility.

Engebøfjellet, Bh8/81.2m



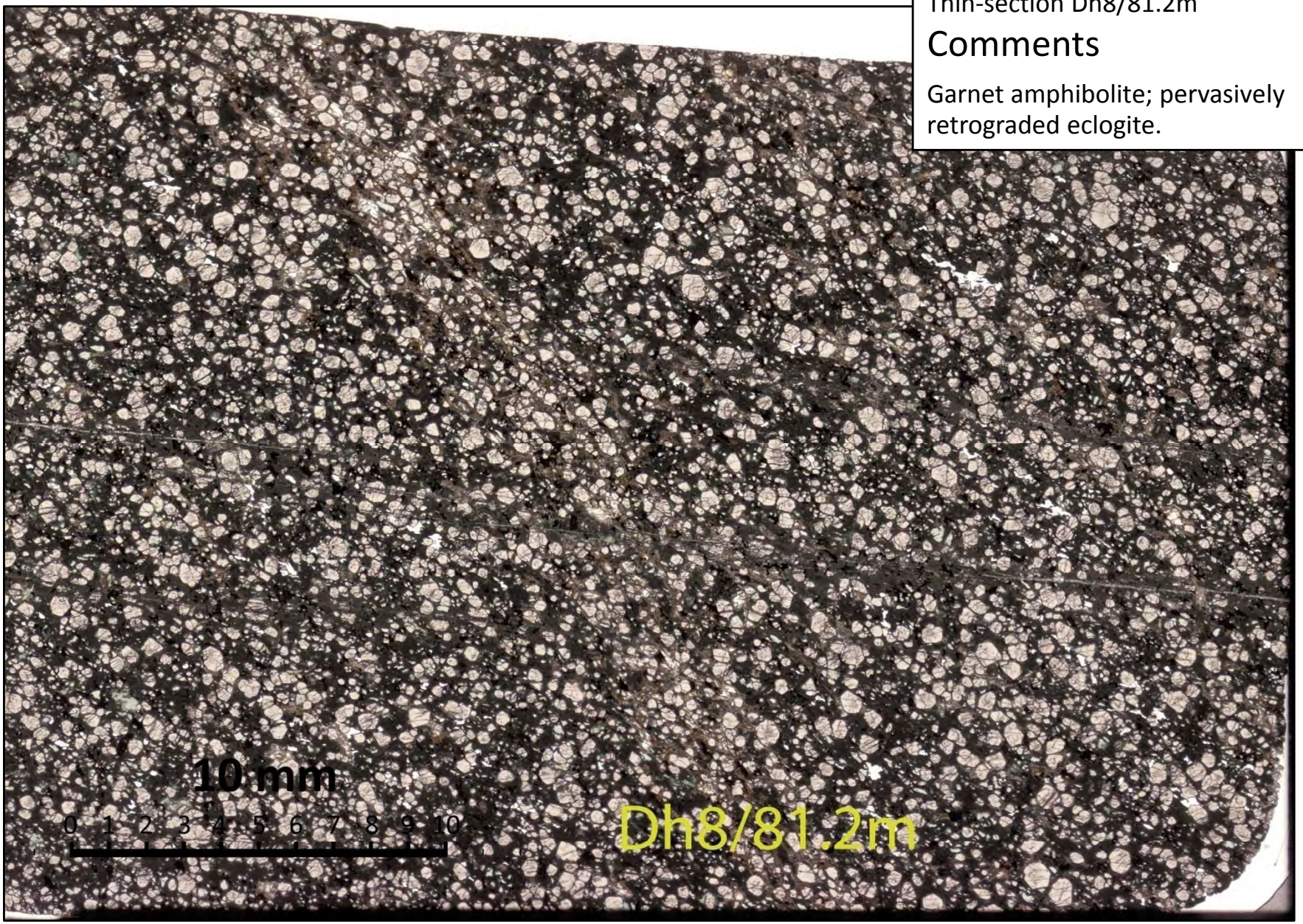
Key information

- Garnet amphibolite (significantly retrograded eclogite)
- Magnetic susceptibility: 0.00759 (SI-units)
- Specific gravity: 3.41 g/cm^3
- 2.7 % TiO_2 , 16.7 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

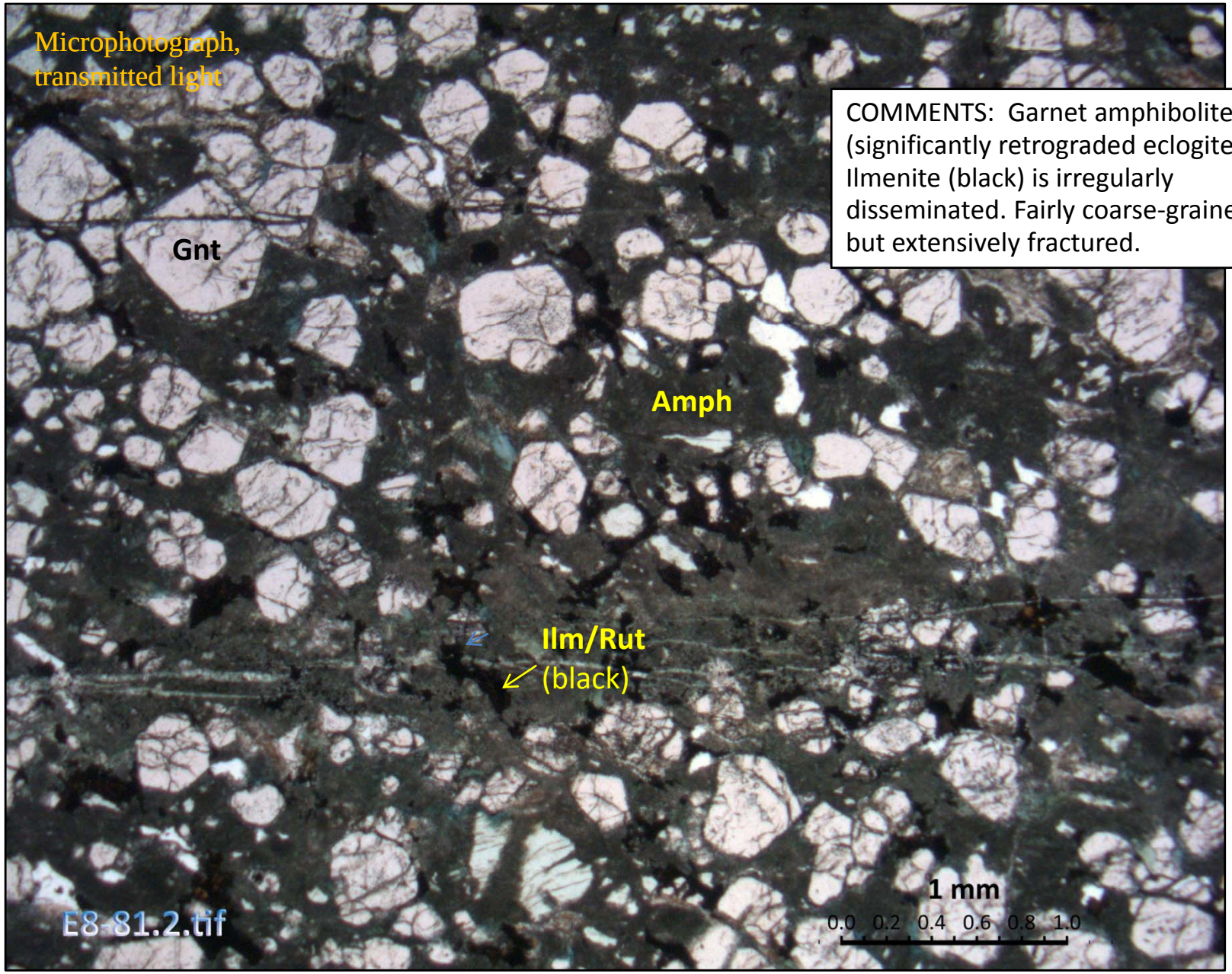
Thin-section Dh8/81.2m

Comments

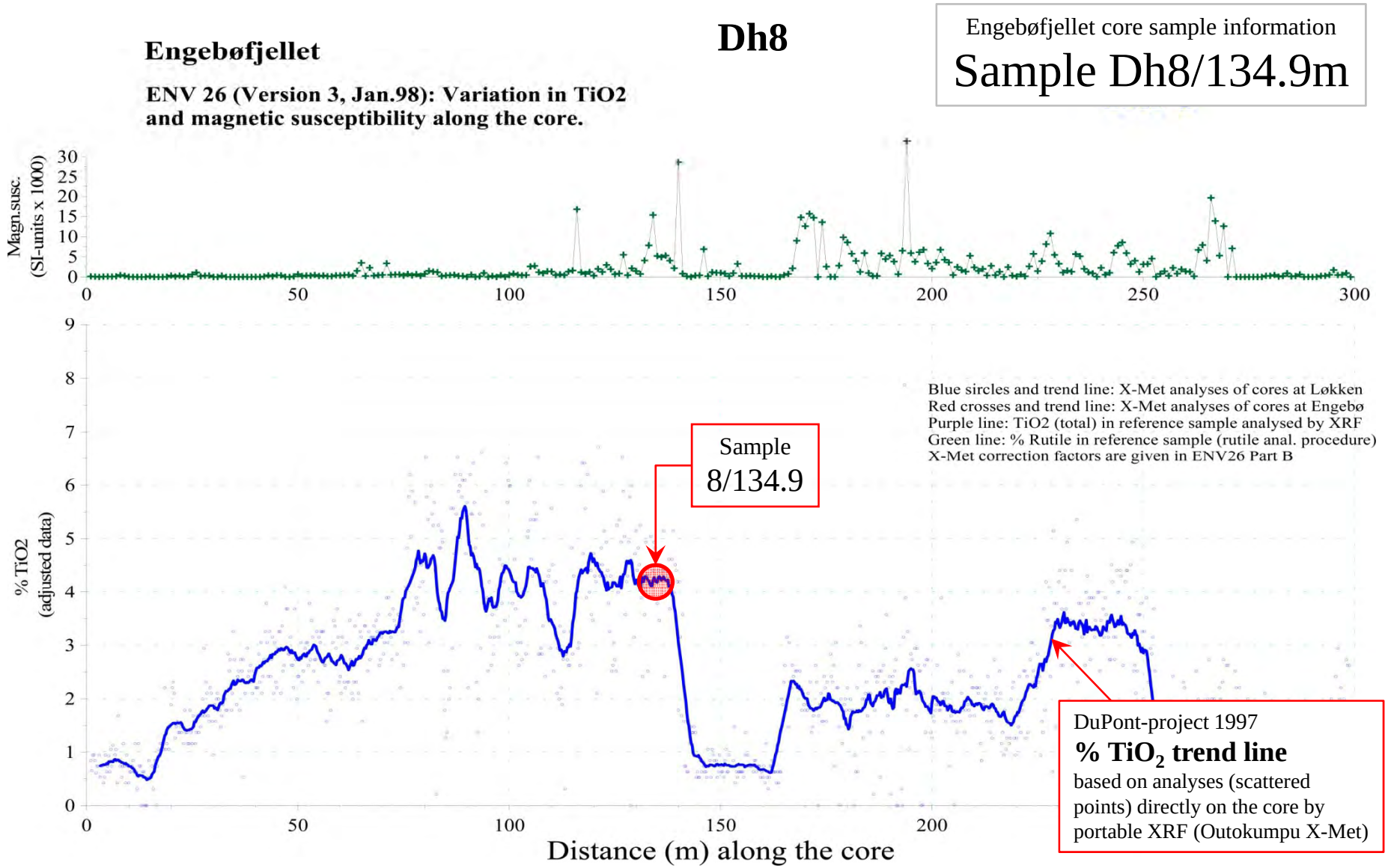
Garnet amphibolite; pervasively retrograded eclogite.



Engebøfjellet, Bh8/81.2m



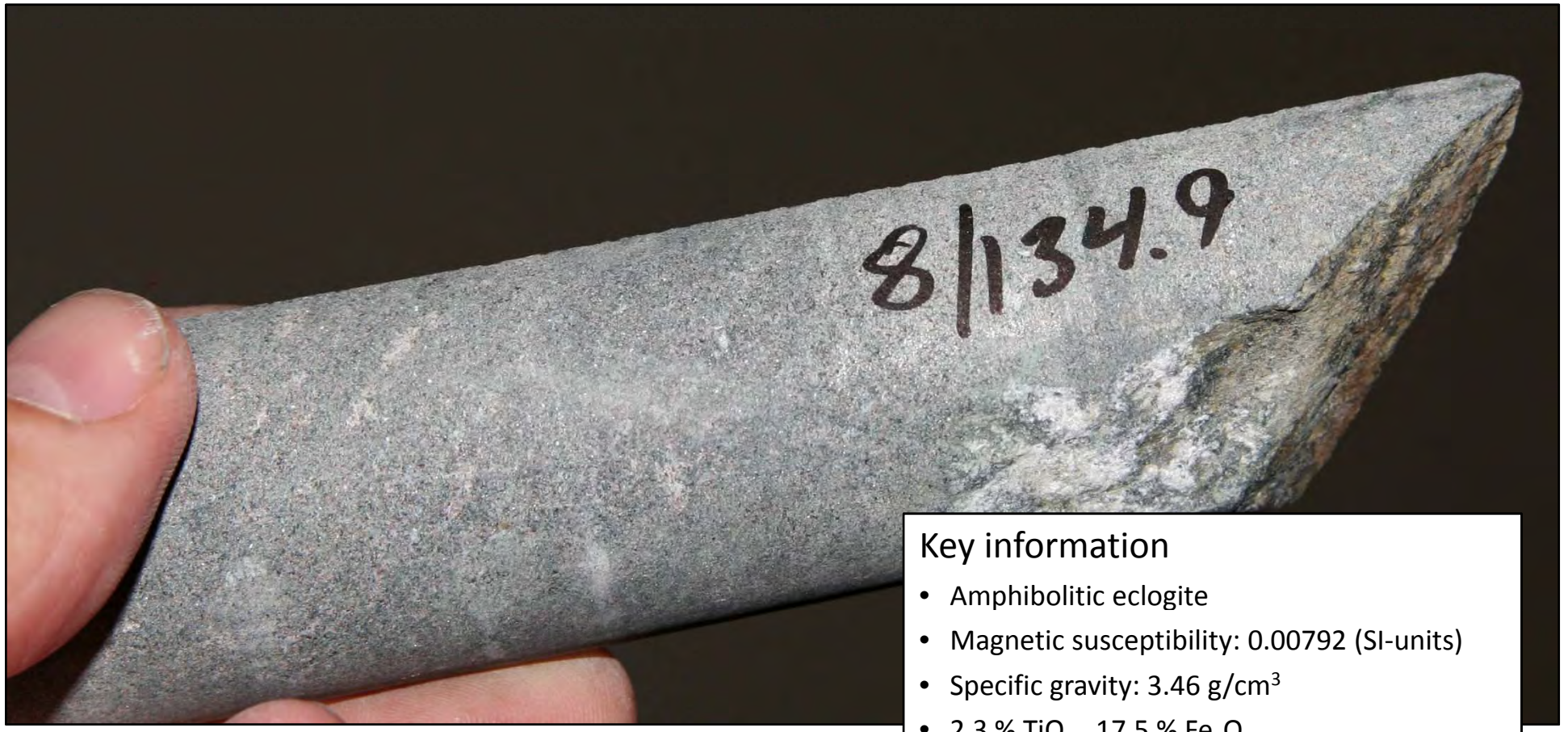
COMMENTS: Garnet amphibolite (significantly retrograded eclogite). Ilmenite (black) is irregularly disseminated. Fairly coarse-grained garnet, but extensively fractured.


Engebøfjellet
Dh8
ENV 26 (Version 3, Jan.98): Variation in TiO2
and magnetic susceptibility along the core.
Engebøfjellet core sample information
Sample Dh8/134.9m
Magn.susc.
(SI-units x 1000)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
% TiO2
(adjusted data)
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
Distance (m) along the core
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Sample
8/134.9
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Amphibolitic eclogite; extensively retrograded; probably representative for a large volume of rock in this part of the deposit.

Engebøfjellet, Bh8/134.9m



Key information

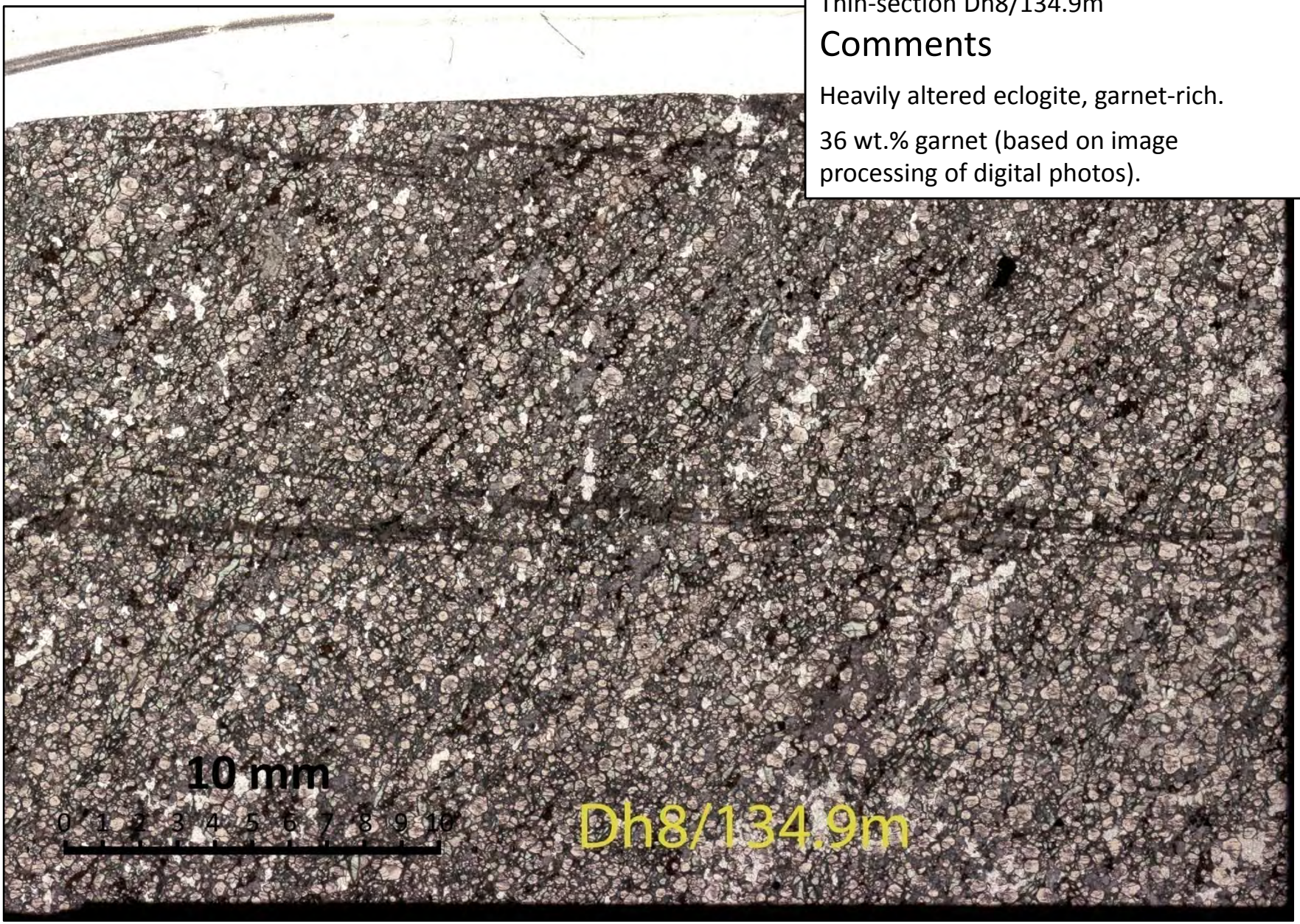
- Amphibolitic eclogite
- Magnetic susceptibility: 0.00792 (SI-units)
- Specific gravity: 3.46 g/cm^3
- 2.3 % TiO_2 , 17.5 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

Thin-section Dh8/134.9m

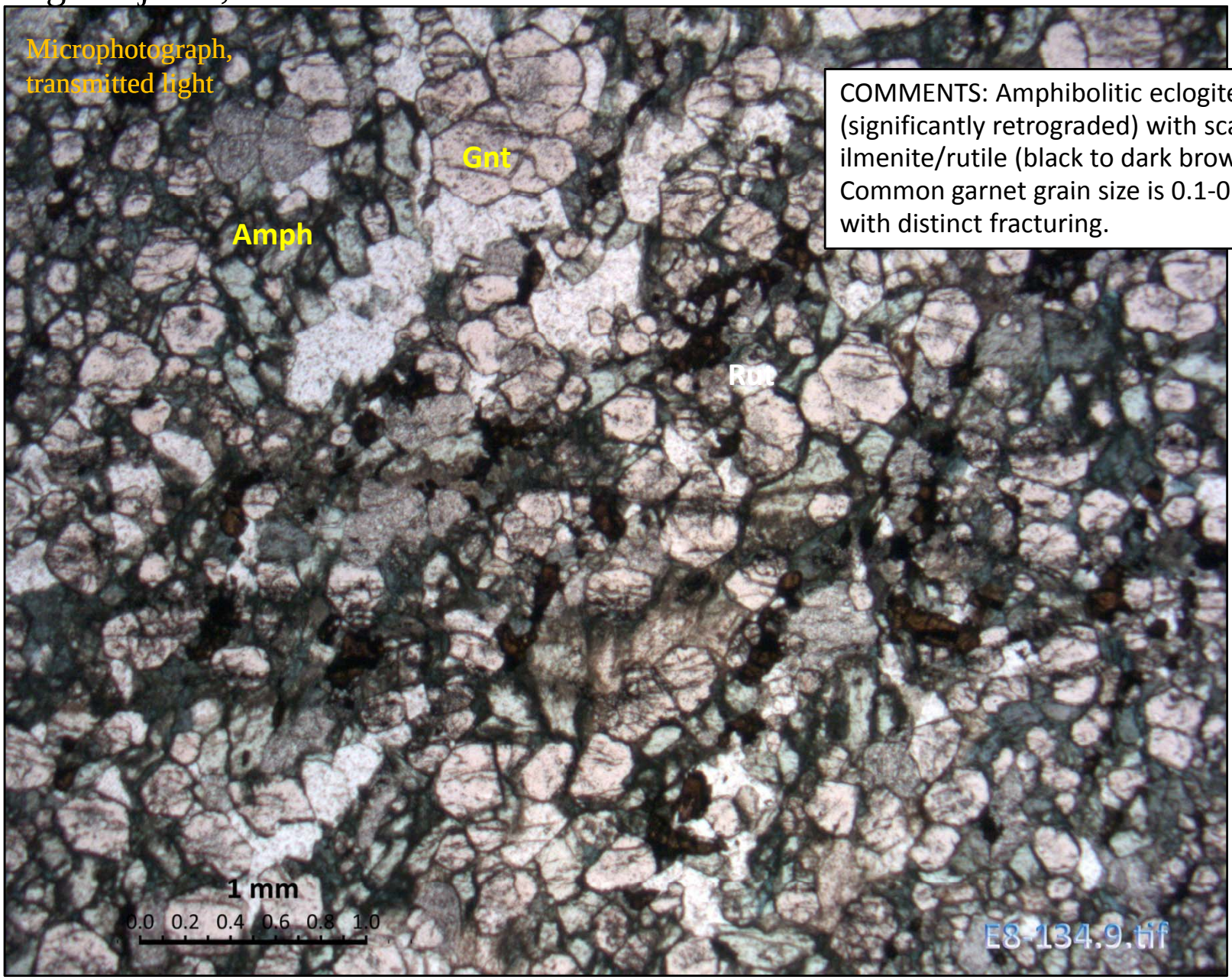
Comments

Heavily altered eclogite, garnet-rich.

36 wt.% garnet (based on image processing of digital photos).



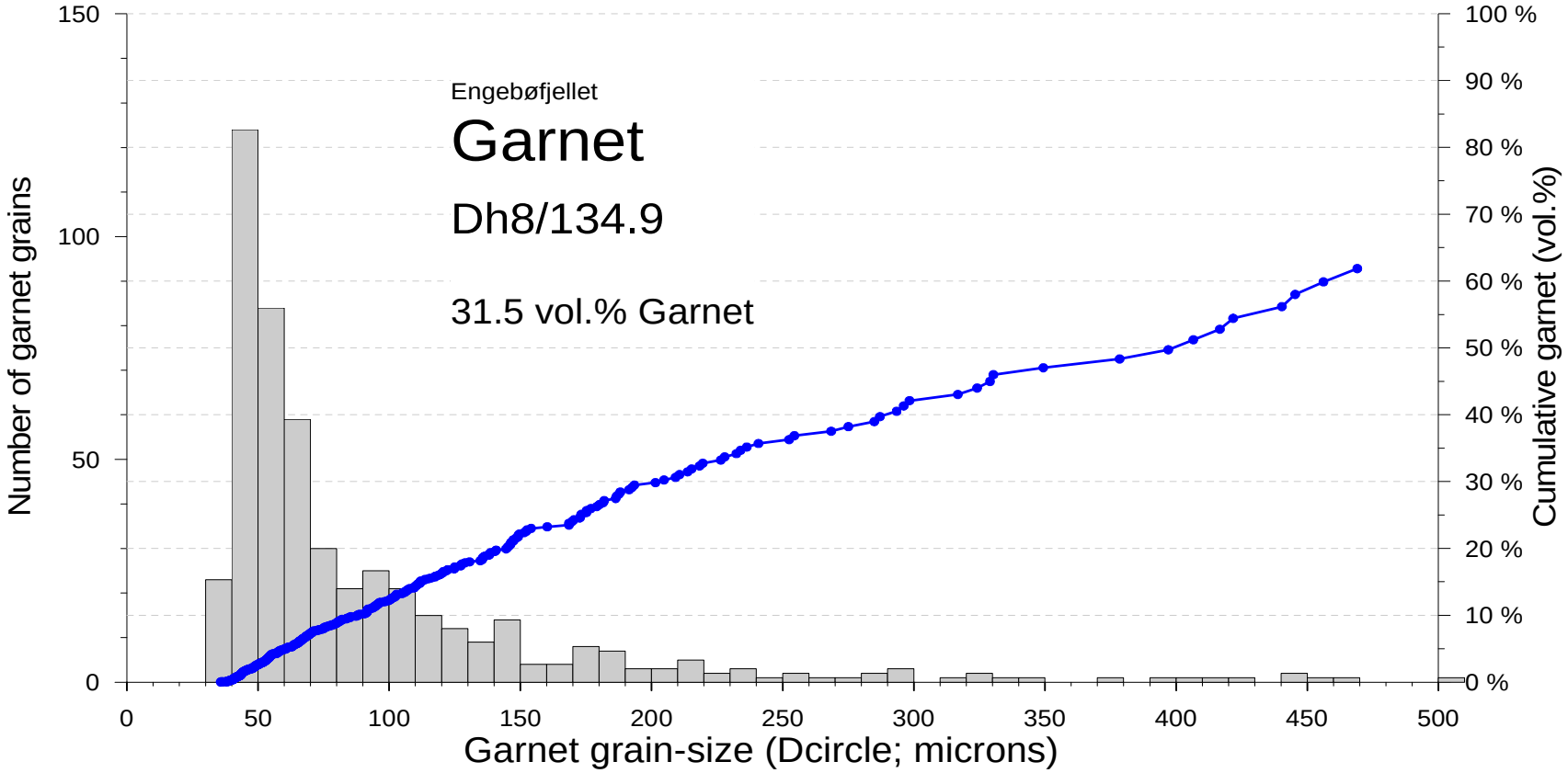
Engebøfjellet, Bh8/134.9m

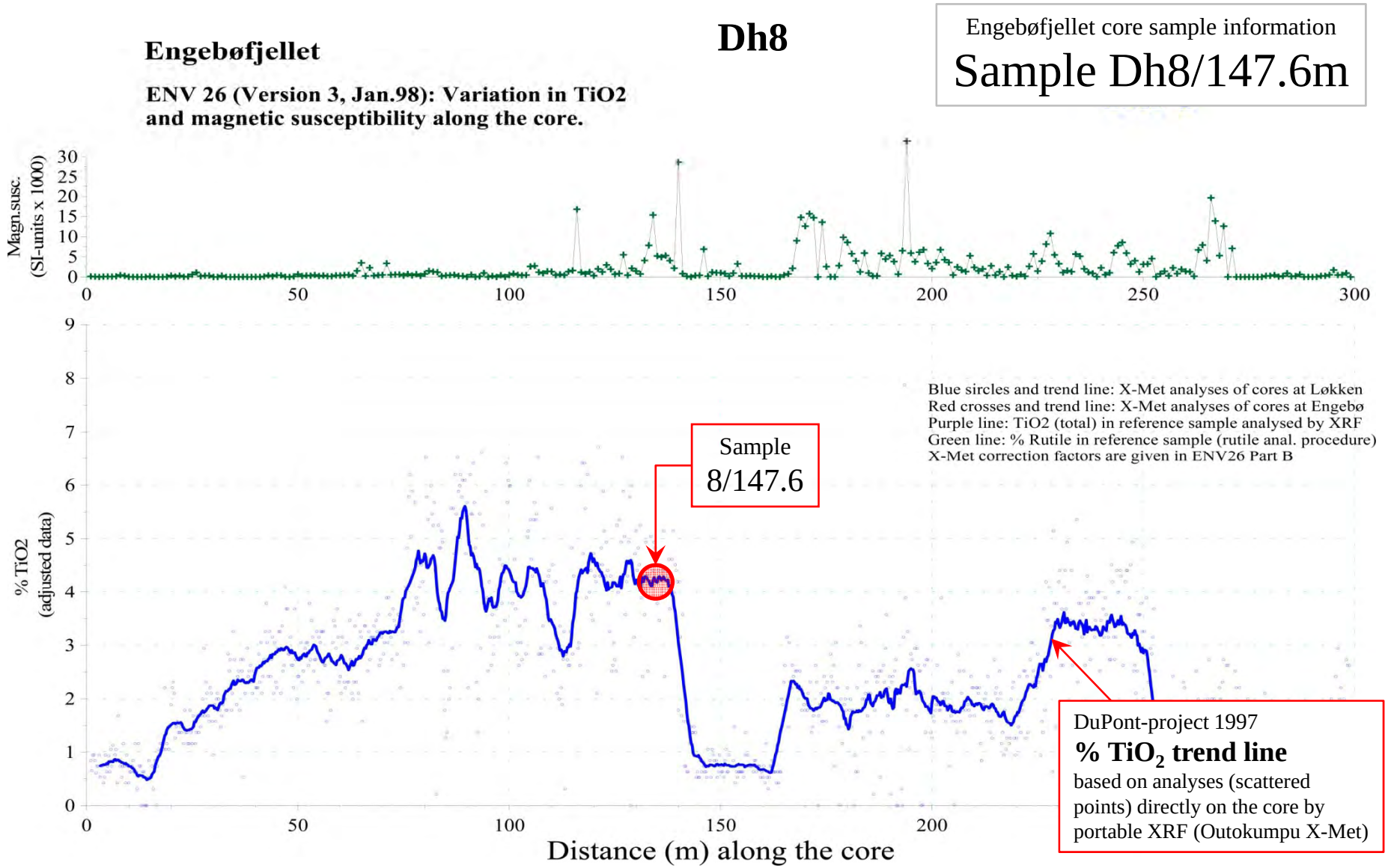


COMMENTS: Amphibolitic eclogite (significantly retrograded) with scattered ilmenite/rutile (black to dark brownish). Common garnet grain size is 0.1-0.3 mm, with distinct fracturing.

Comments

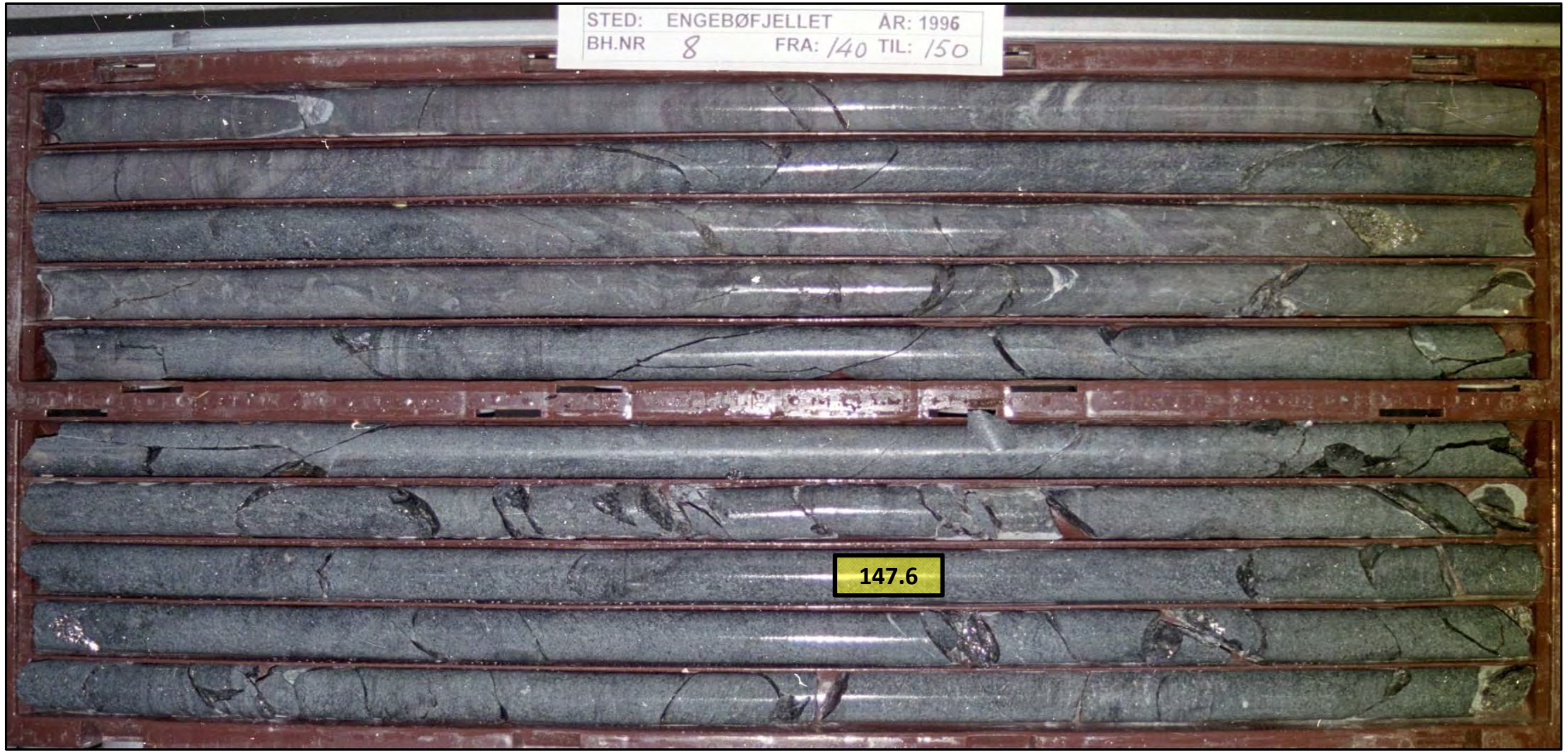
Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet is less than 400 microns. However, since grains attached to each other is registered as one larger grain by this method, the real garnet 50 vol. % boundary is probably below 400 microns.




Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2
and magnetic susceptibility along the core.
Dh8
Engebøfjellet core sample information
Sample Dh8/147.6m
Magn.susc.
(SI-units x 1000)
0
5
10
15
20
25
30
0
50
100
150
200
250
300
% TiO2
(adjusted data)
0
1
2
3
4
5
6
7
8
9
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Sample
8/147.6
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)
Distance (m) along the core

Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Amphibolitic eclogite; extensively retrograded; probably representative for a large volume of rock in this part of the deposit.



Engebøfjellet, Bh8/147.6m

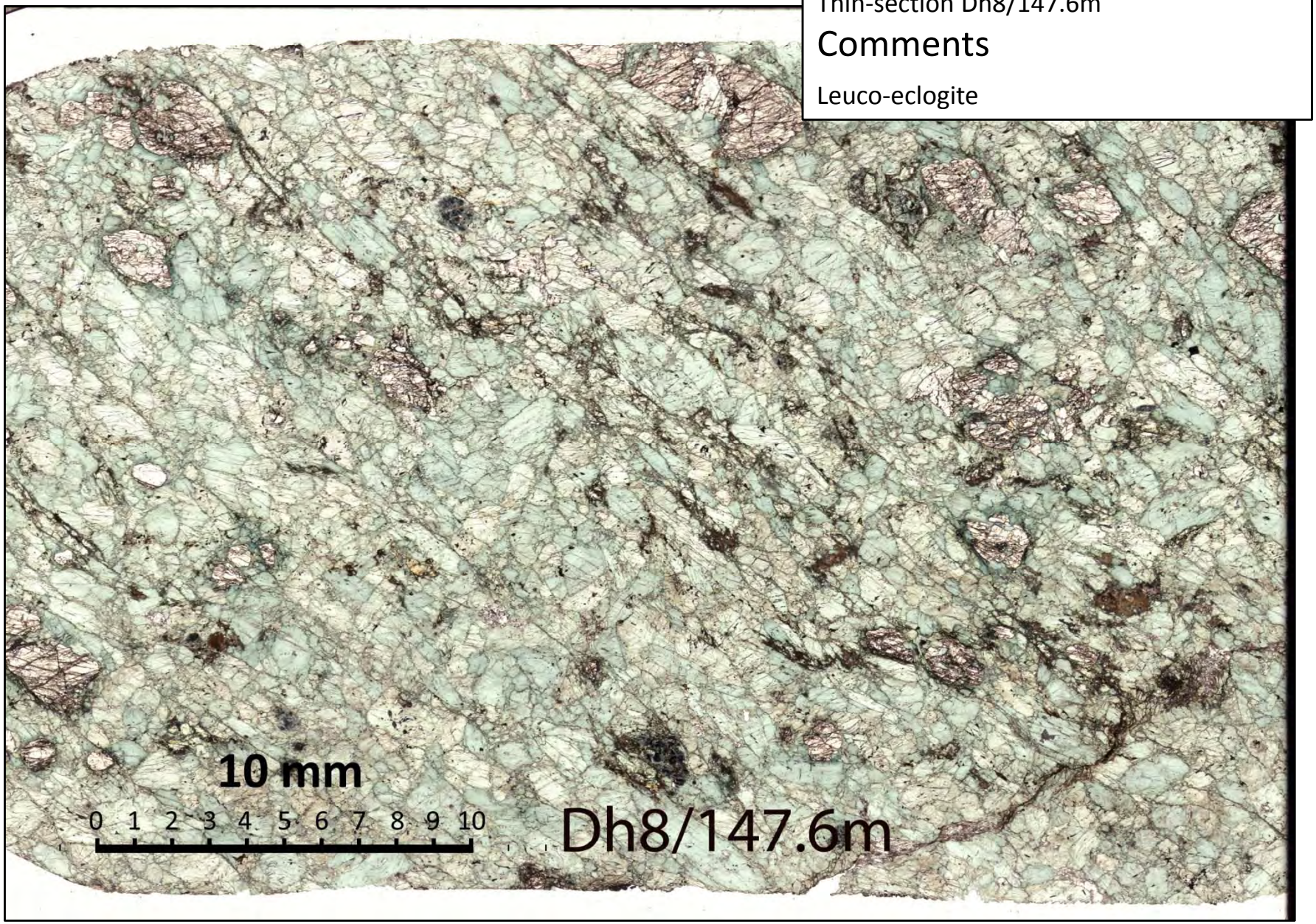
Key information

- Garnet amphibolite (amphibolitic eclogite)
- Magnetic susceptibility: 0.00144 (SI-units)
- Specific gravity: 3.11 g/cm^3
- 0.3 % TiO_2 , 11.5 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

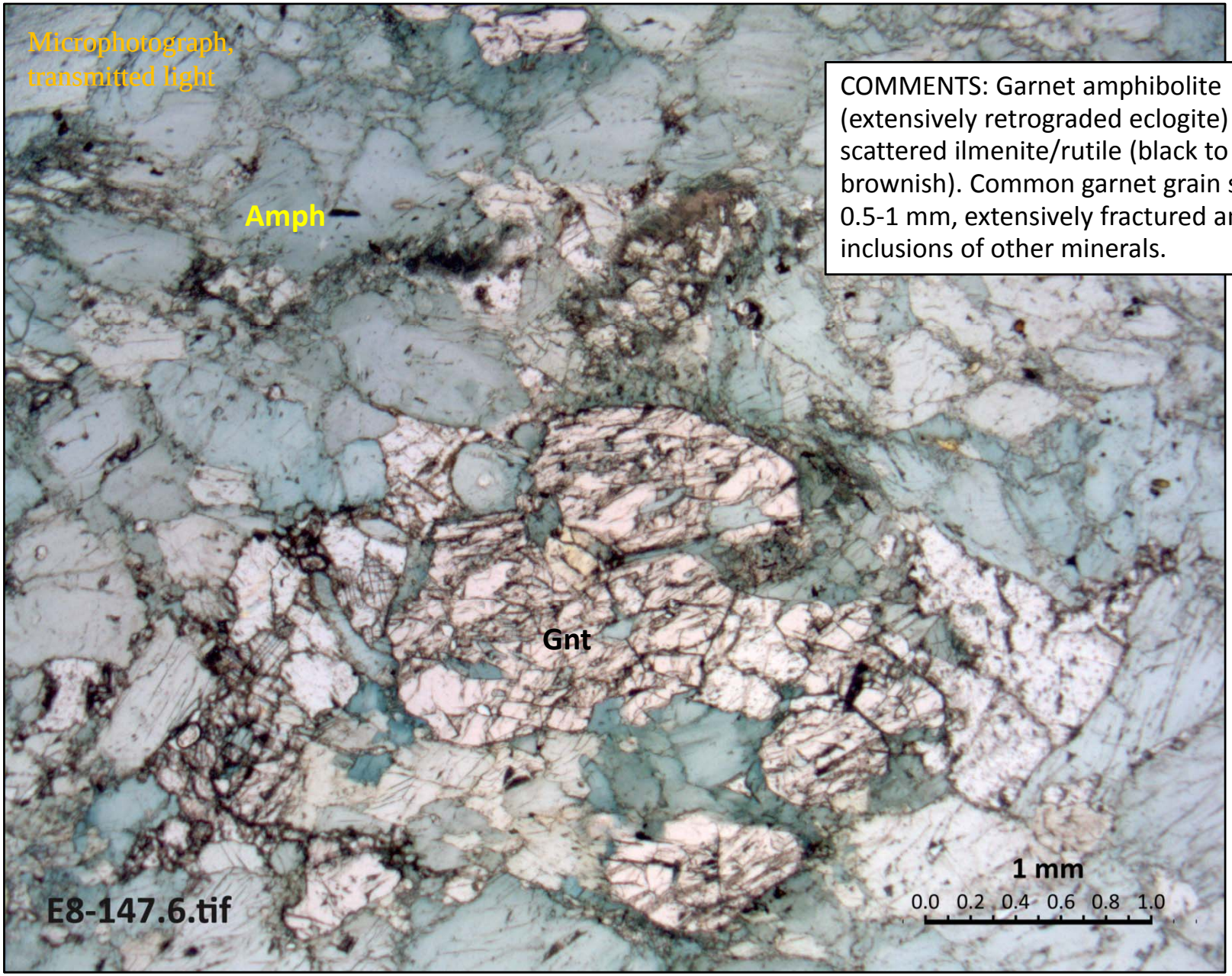
Thin-section Dh8/147.6m

Comments

Leuco-eclogite



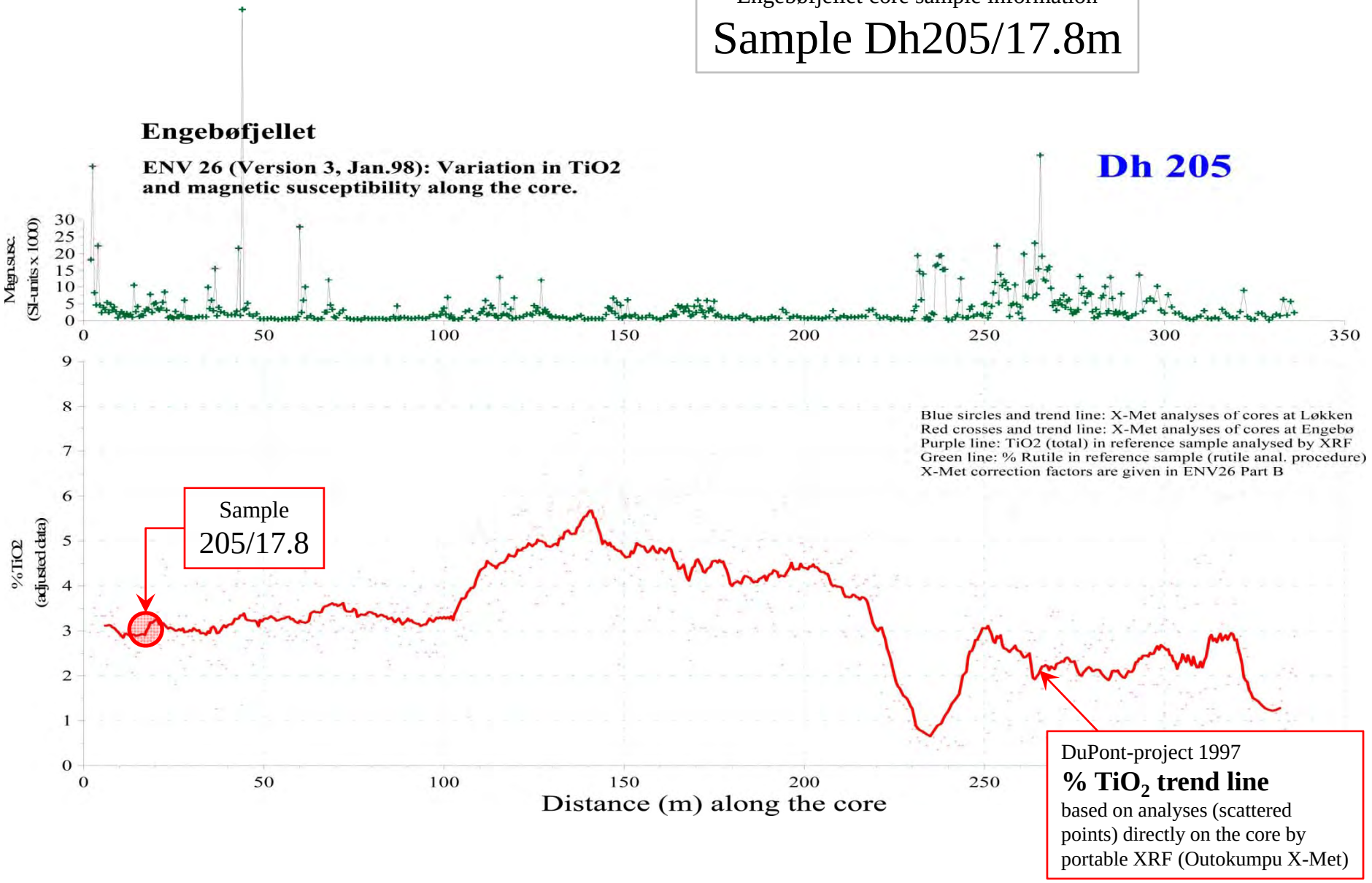
Engebøfjellet, Bh8/147.6m



COMMENTS: Garnet amphibolite (extensively retrograded eclogite) with scattered ilmenite/rutile (black to dark brownish). Common garnet grain size is 0.5-1 mm, extensively fractured and with inclusions of other minerals.

Engebøfjellet core sample information

Sample Dh205/17.8m



Comments - 10 m core section

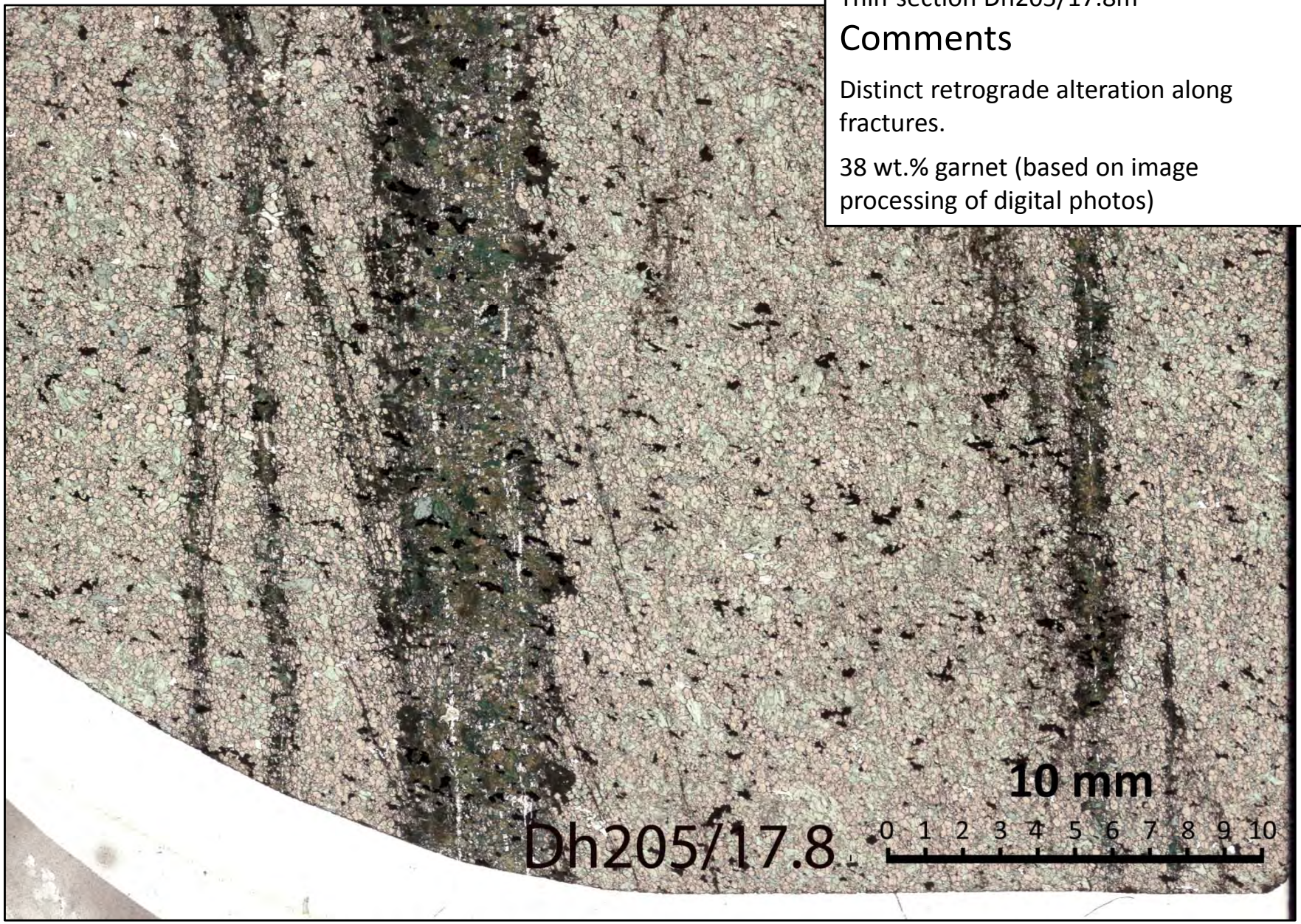
- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; retrograde alteration along fractures; representative for a large amounts of eclogite in this part of the deposit.

Thin-section Dh205/17.8m

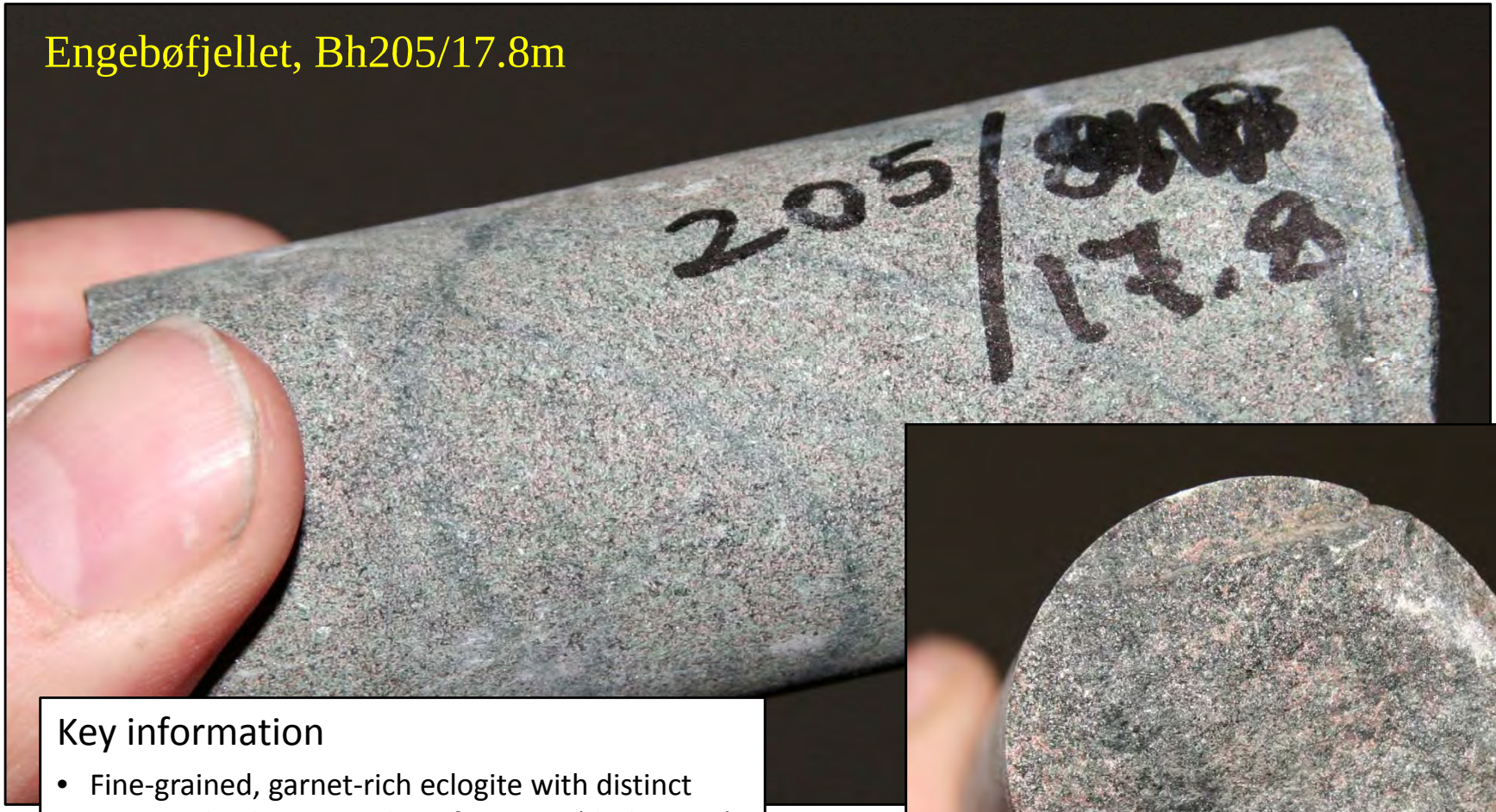
Comments

Distinct retrograde alteration along fractures.

38 wt.% garnet (based on image processing of digital photos)



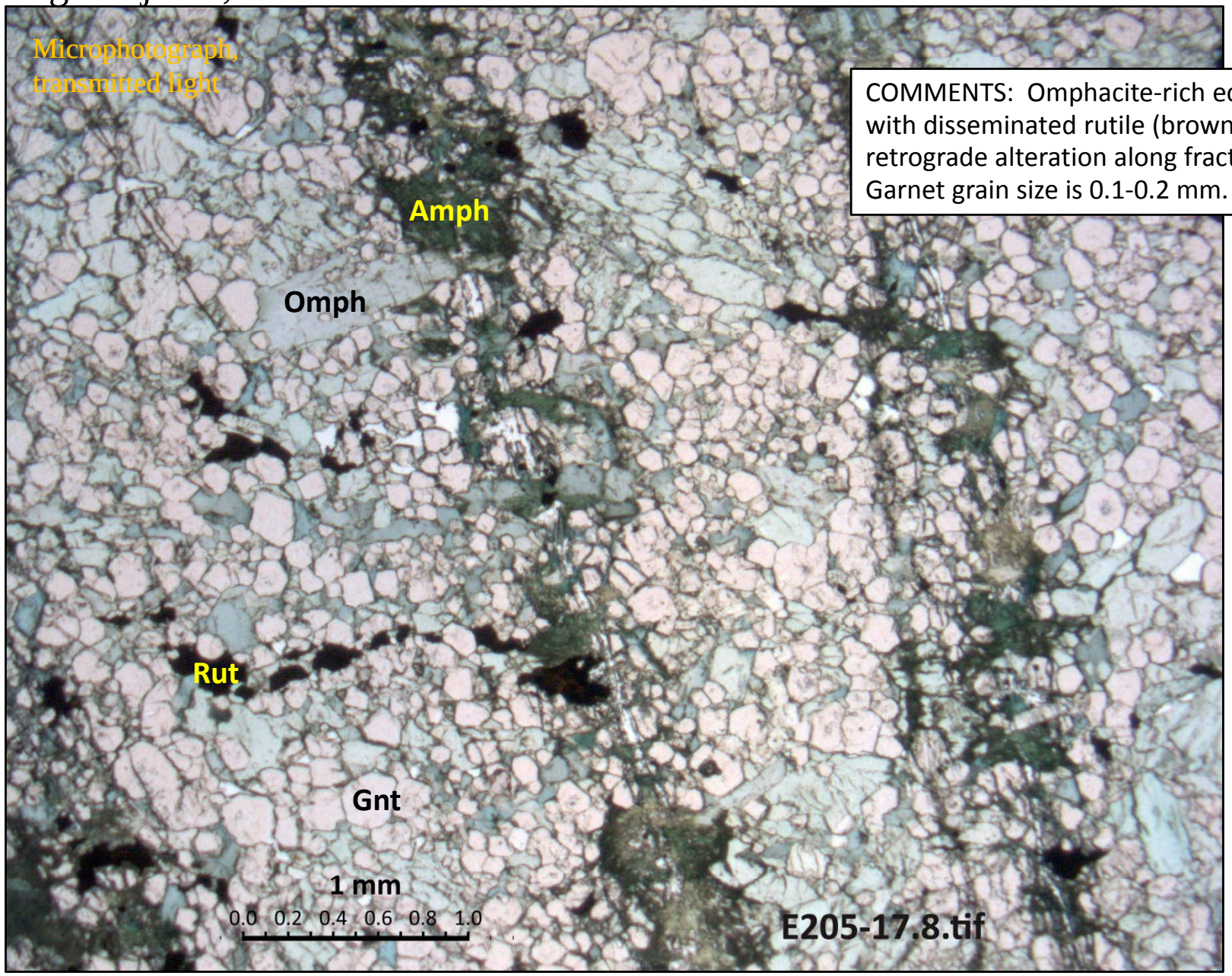
Engebøfjellet, Bh205/17.8m



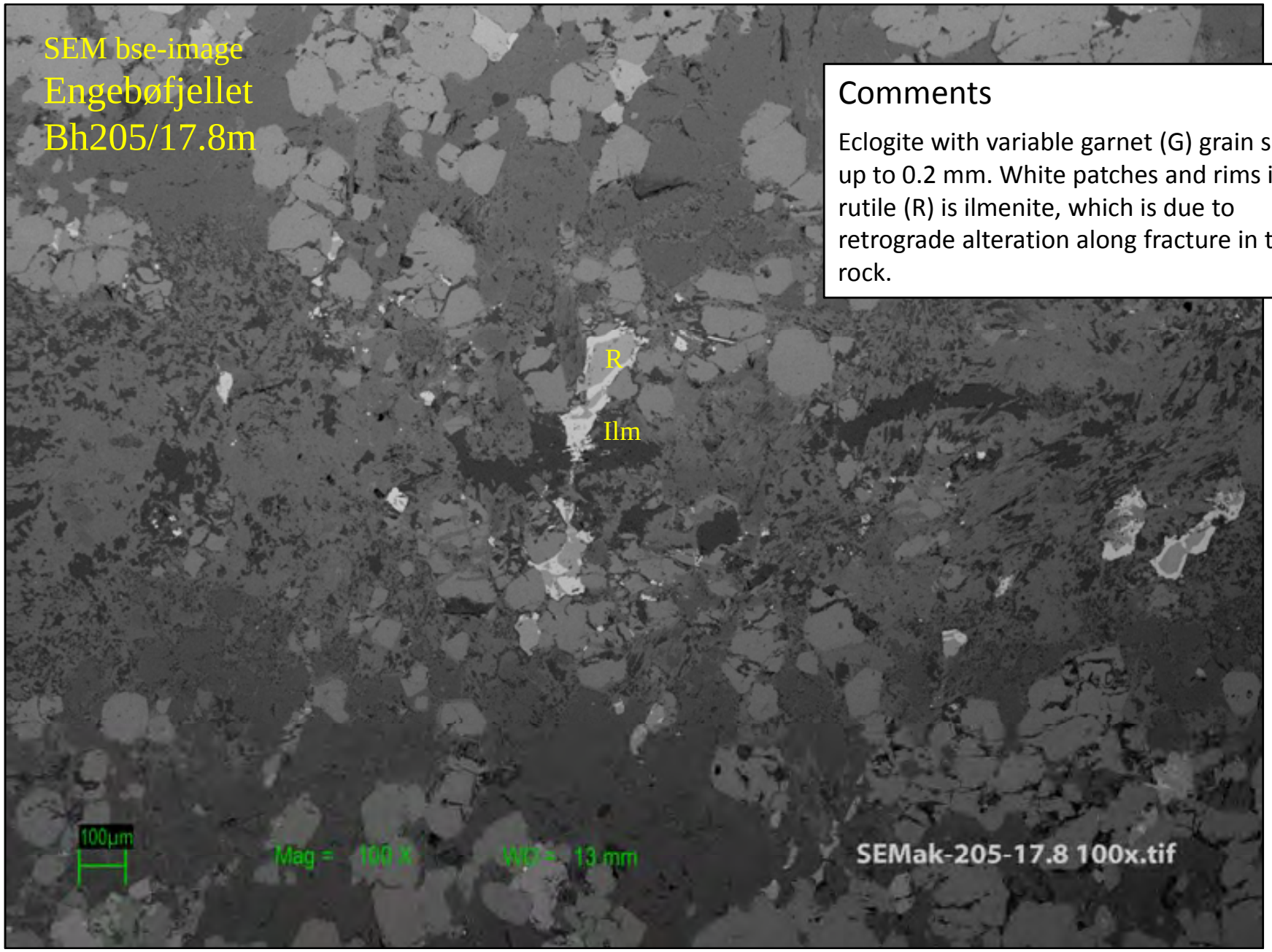
Key information

- Fine-grained, garnet-rich eclogite with distinct retrograde alteration along fractures (dark zones).
- Magnetic susceptibility: 0.00200 (SI-units)
- Specific gravity: 3.60 g/cm^3
- 1.5 % TiO_2 , 18.5 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

Engebøfjellet, Bh205/17.8m



COMMENTS: Omphacite-rich eclogite with disseminated rutile (brownish); retrograde alteration along fracturs. Garnet grain size is 0.1-0.2 mm.

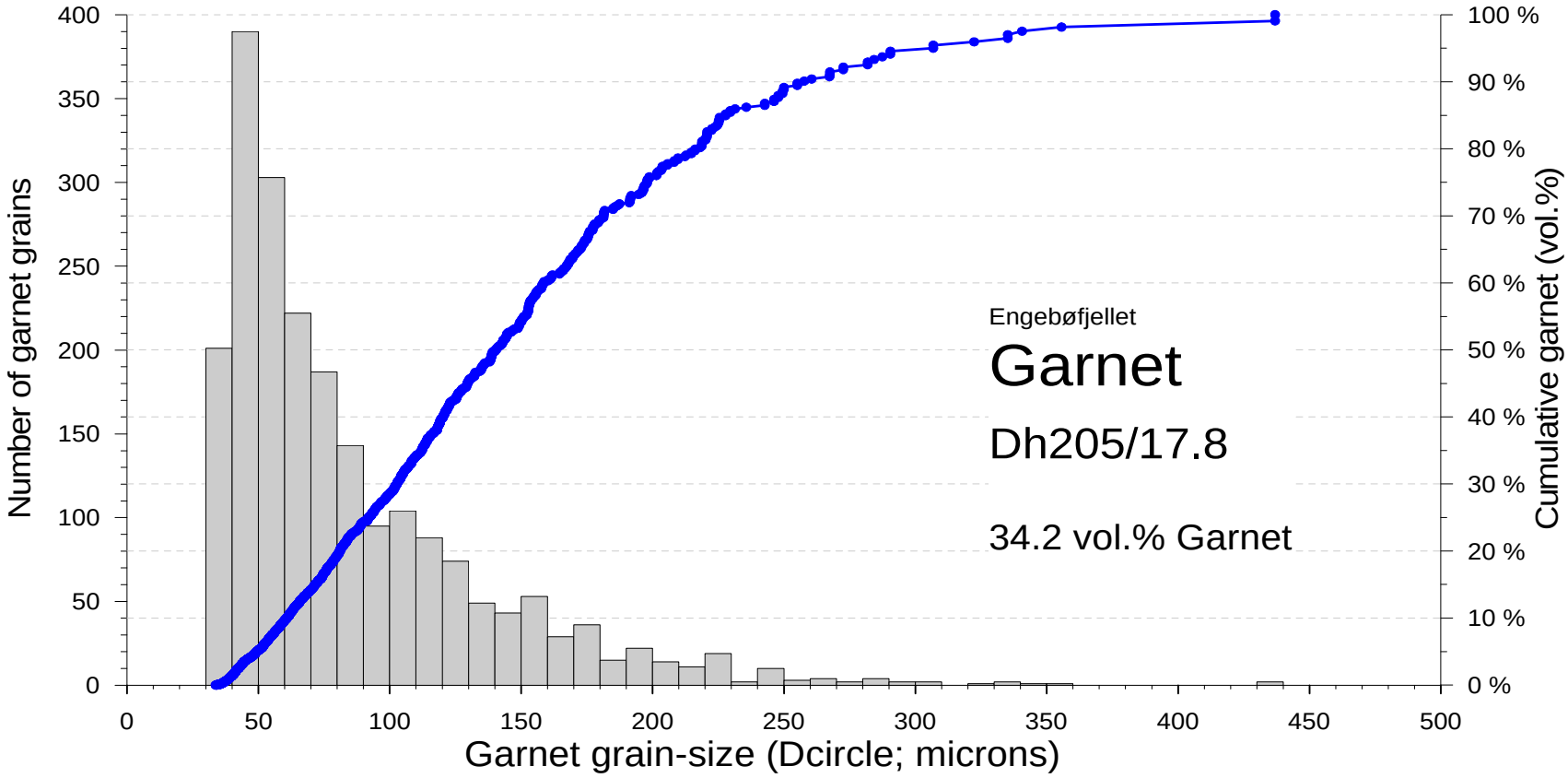


Comments

Eclogite with variable garnet (G) grain size up to 0.2 mm. White patches and rims in rutile (R) is ilmenite, which is due to retrograde alteration along fracture in the rock.

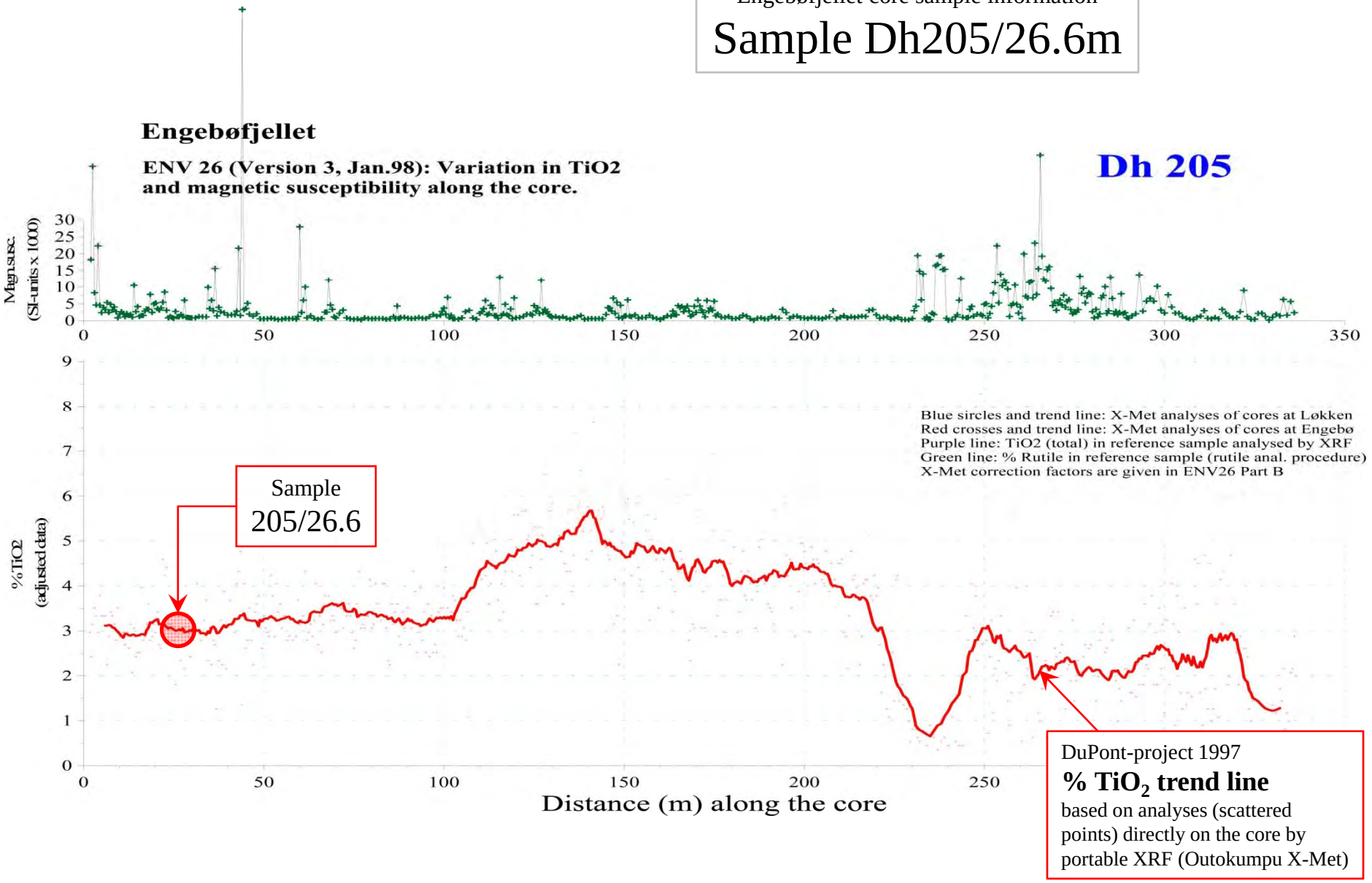
Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet is less than 140 microns. However, since grains attached to each other is registered as one larger grain by this method, the real 50 vol. % boundary is below 140 microns.



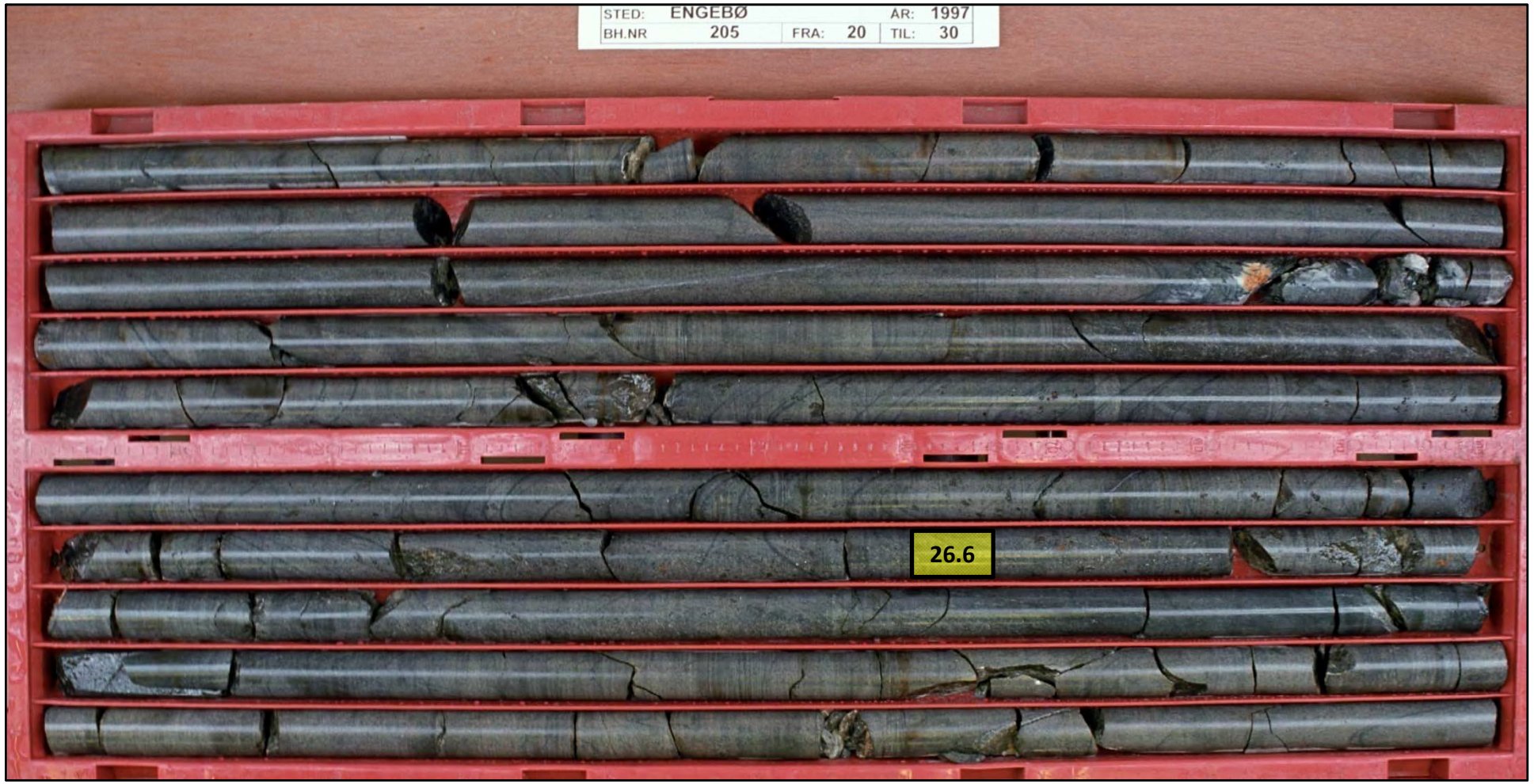
Engebøfjellet core sample information

Sample Dh205/26.6m



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Eclogite; retrograde alteration along fractures; cavities after unknown mineral/fluid/gas?



Engebøfjellet, Bh205/26.6m

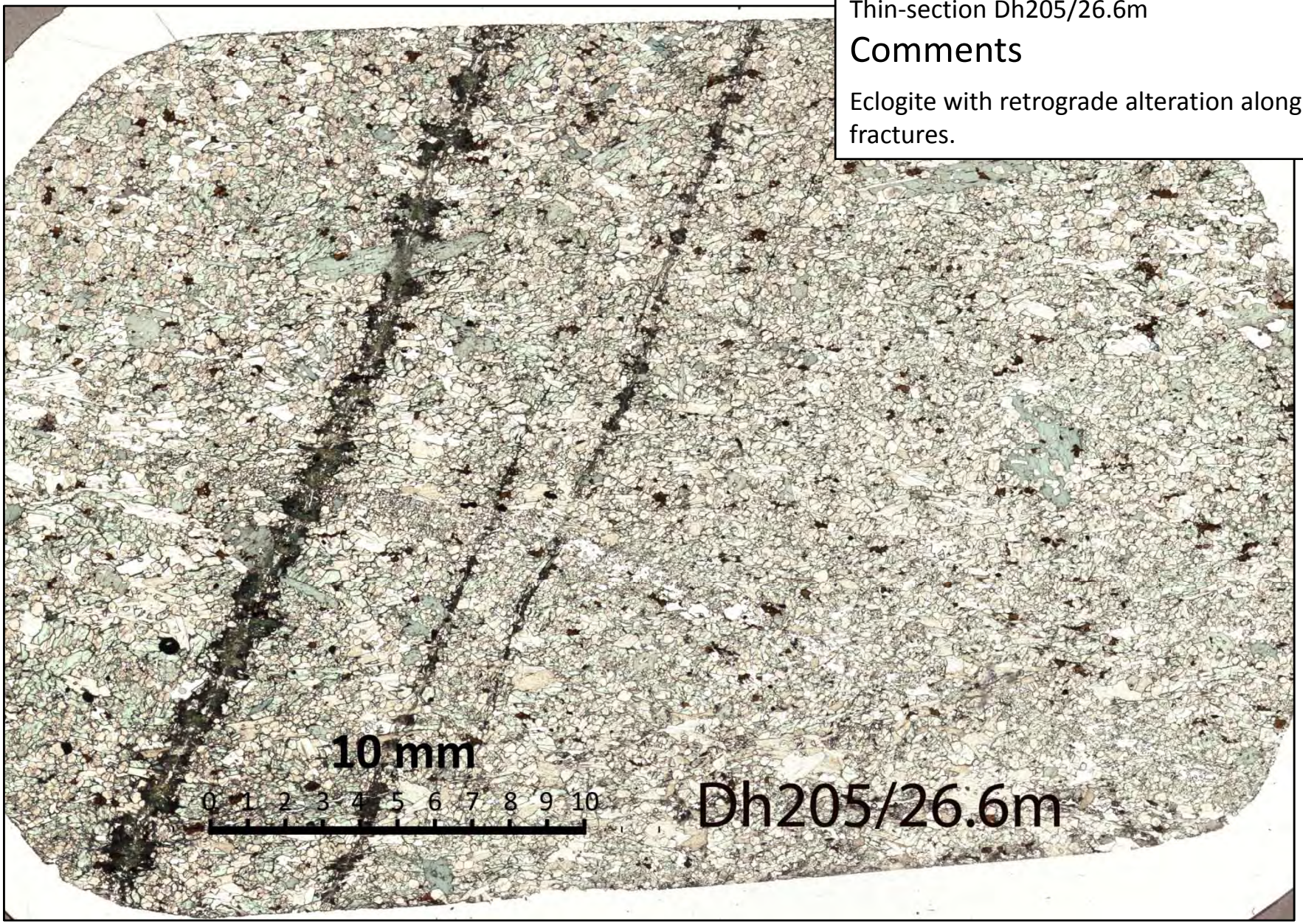
Key information

- Mica-bearing eclogite with holes (dark patches) after unknown mineral or fluid, also (wrongly) called “carbonate cavings”.
- Magnetic susceptibility: 0.00102 (SI-units)
- Specific gravity: 3.39 g/cm^3
- 1.1 % TiO_2 , 14.3 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

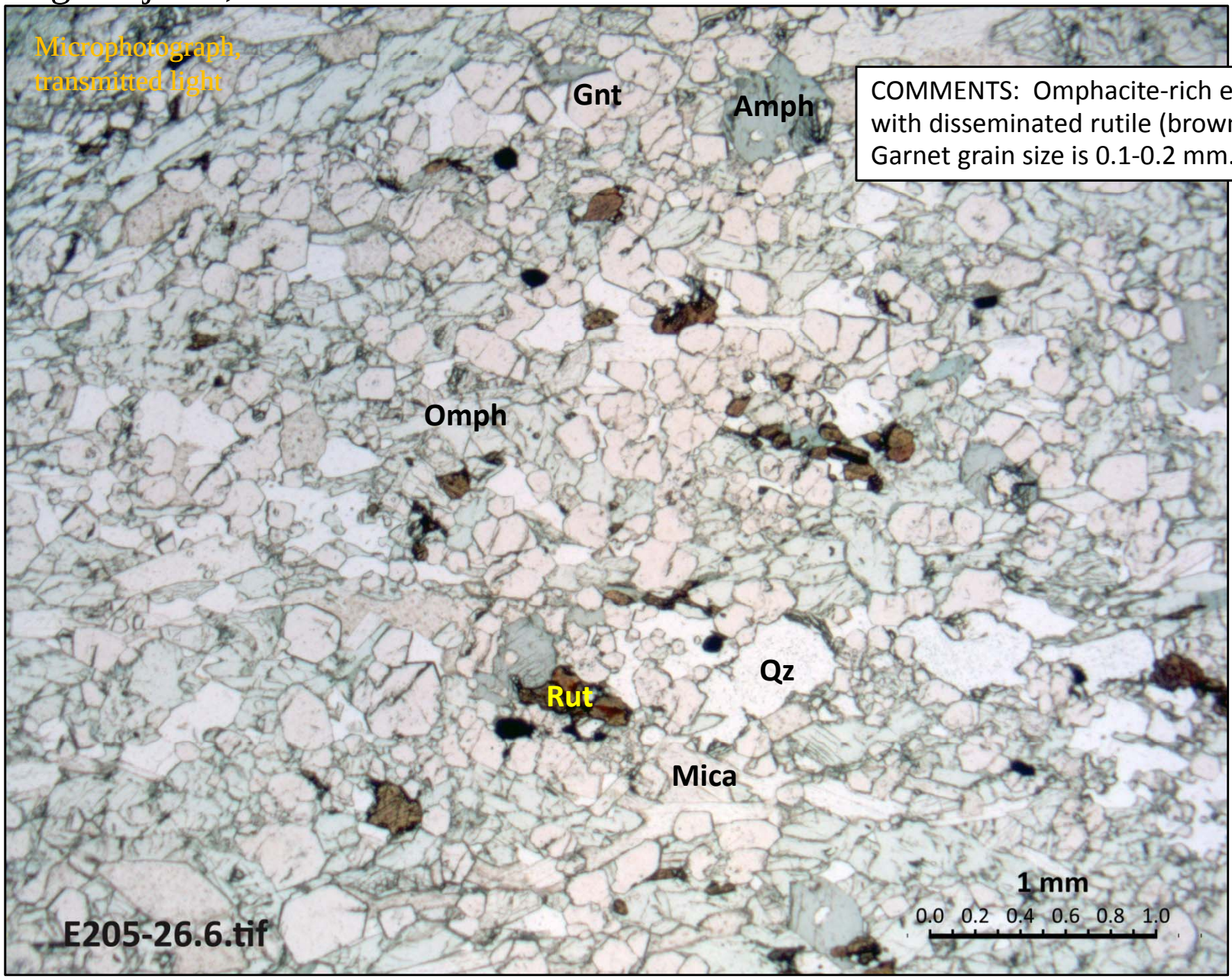
Thin-section Dh205/26.6m

Comments

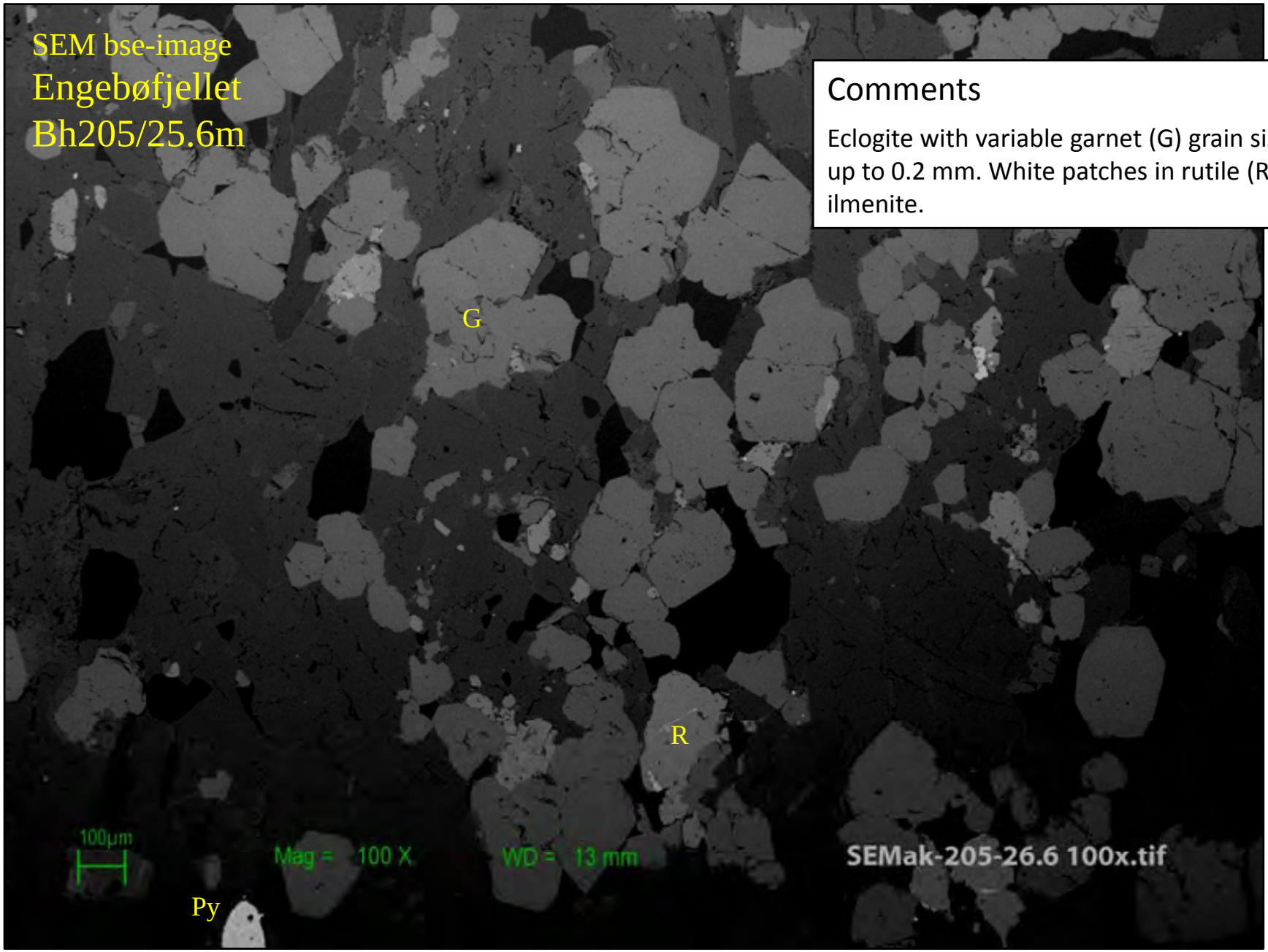
Eclogite with retrograde alteration along fractures.



Engebøfjellet, Bh205/26.6m



COMMENTS: Omphacite-rich eclogite with disseminated rutile (brownish). Garnet grain size is 0.1-0.2 mm.

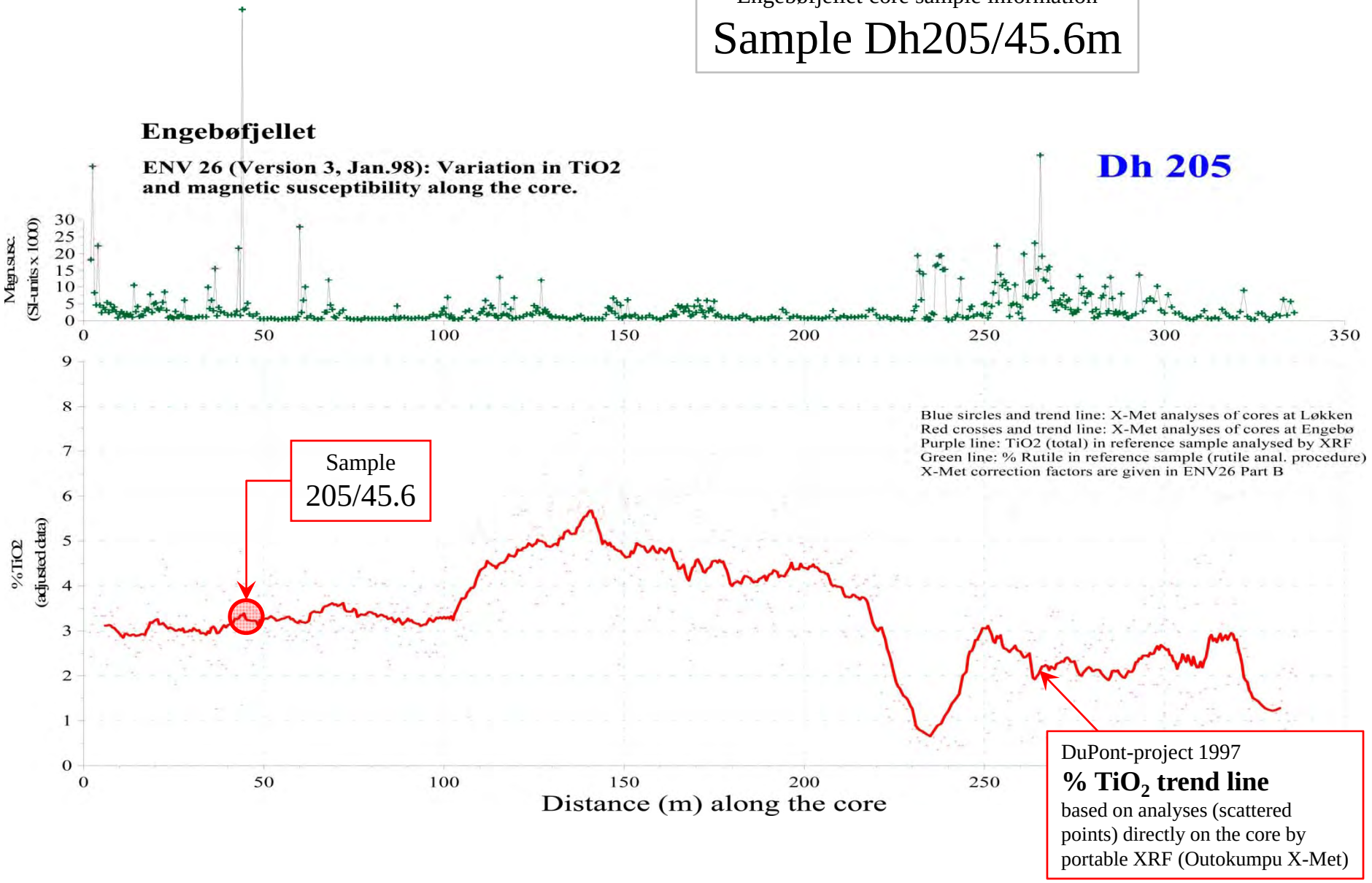


Comments

Eclogite with variable garnet (G) grain size up to 0.2 mm. White patches in rutile (R) is ilmenite.

Engebøfjellet core sample information

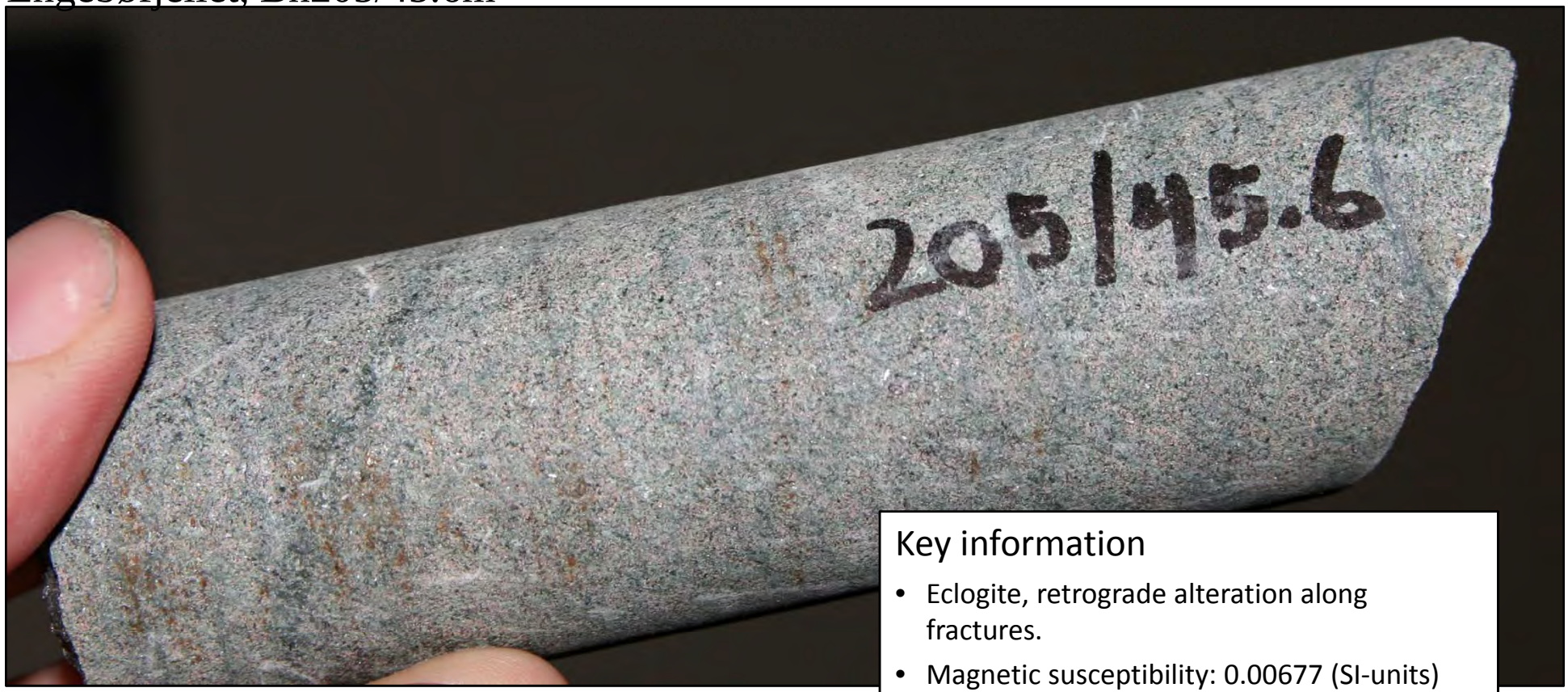
Sample Dh205/45.6m



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; retrograde alteration along fractures; representative for a large amounts of eclogite in this part of the deposit.

Engebøfjellet, Bh205/45.6m



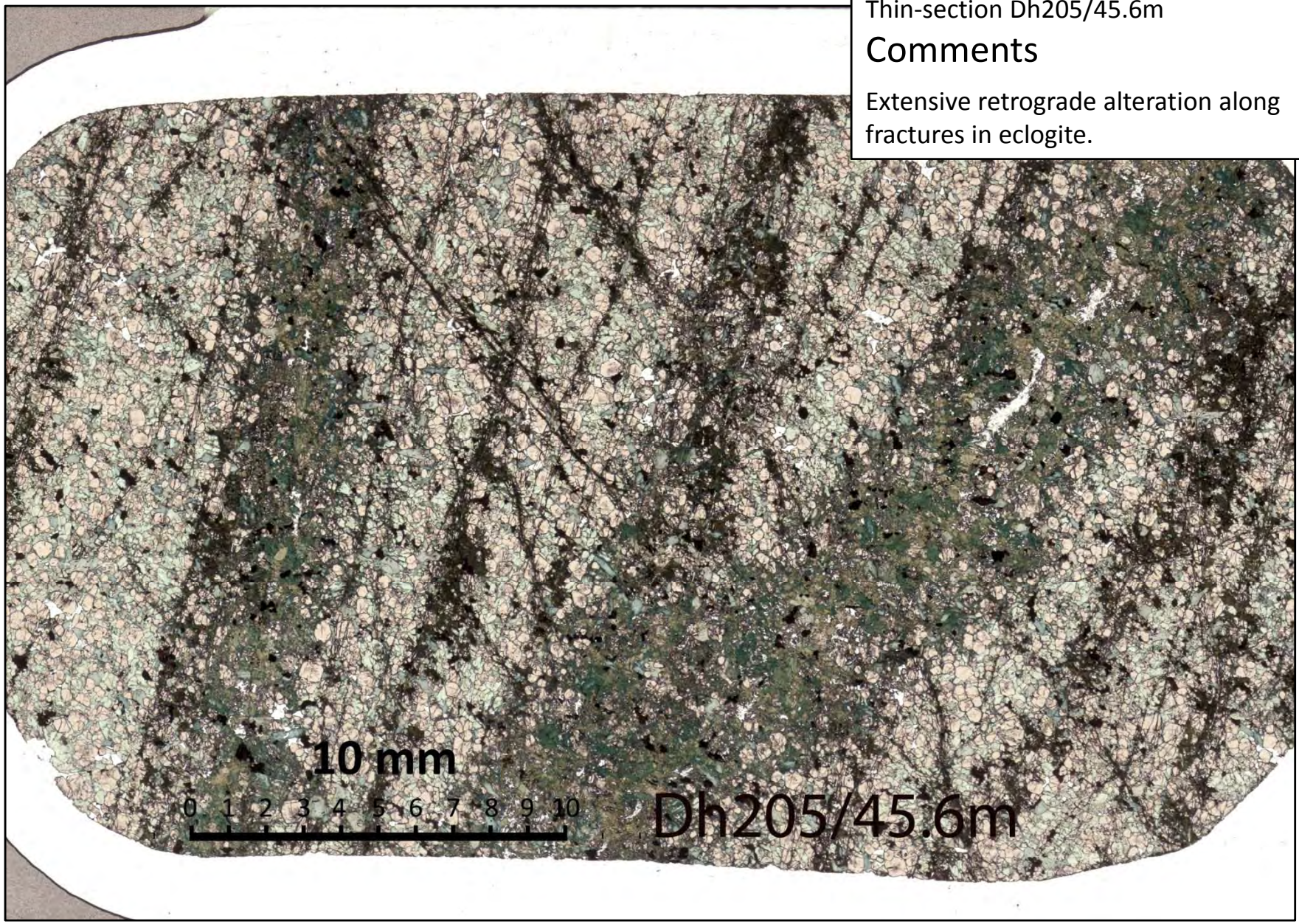
Key information

- Eclogite, retrograde alteration along fractures.
- Magnetic susceptibility: 0.00677 (SI-units)
- Specific gravity: 3.51 g/cm^3
- 1.5 % TiO_2 , 18.1 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

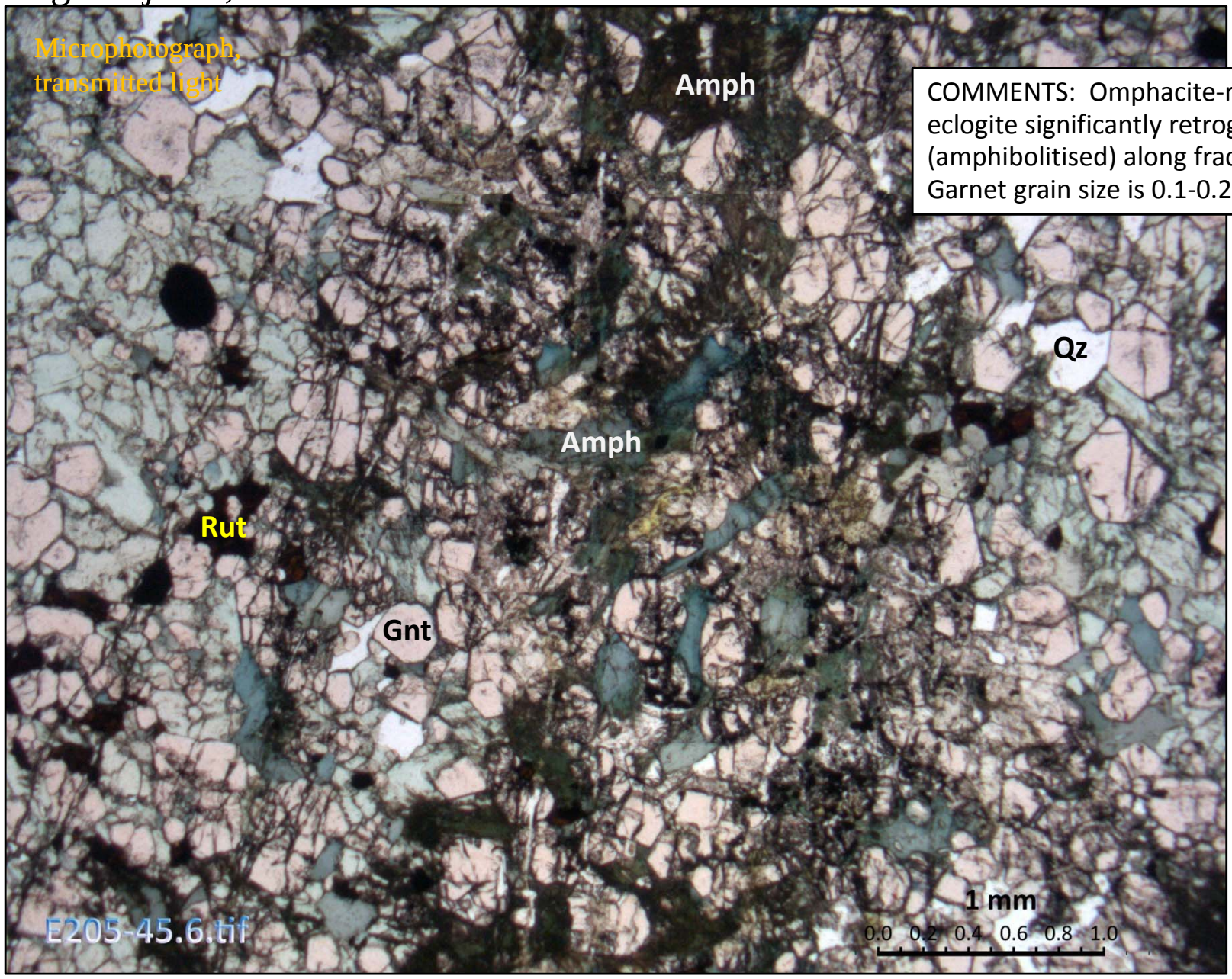
Thin-section Dh205/45.6m

Comments

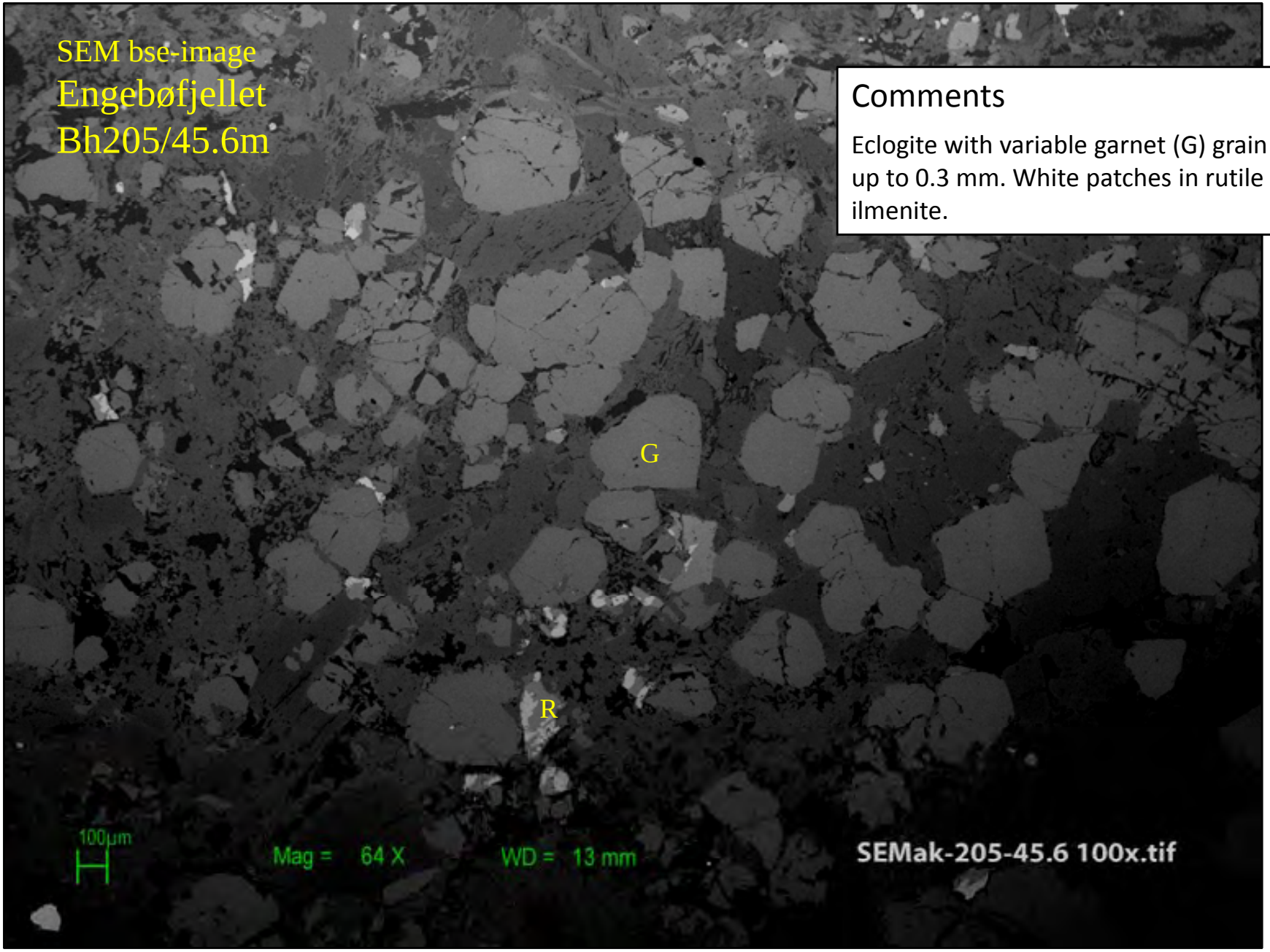
Extensive retrograde alteration along fractures in eclogite.



Engebøfjellet, Bh205/45.6m



COMMENTS: Omphacite-rich eclogite significantly retrograded (amphibolitised) along fractures. Garnet grain size is 0.1-0.2 mm.

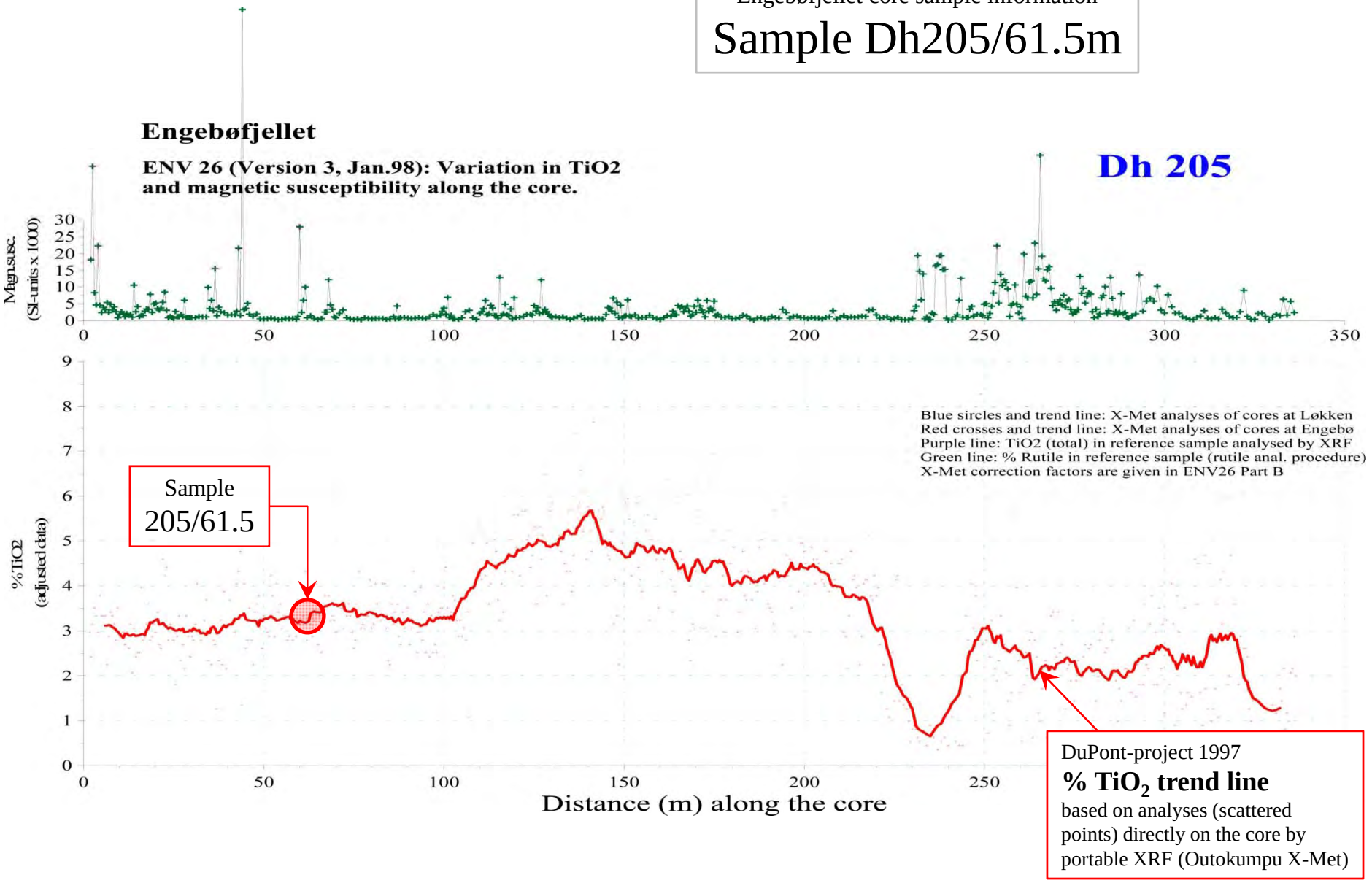


Comments

Eclogite with variable garnet (G) grain size up to 0.3 mm. White patches in rutile (R) is ilmenite.

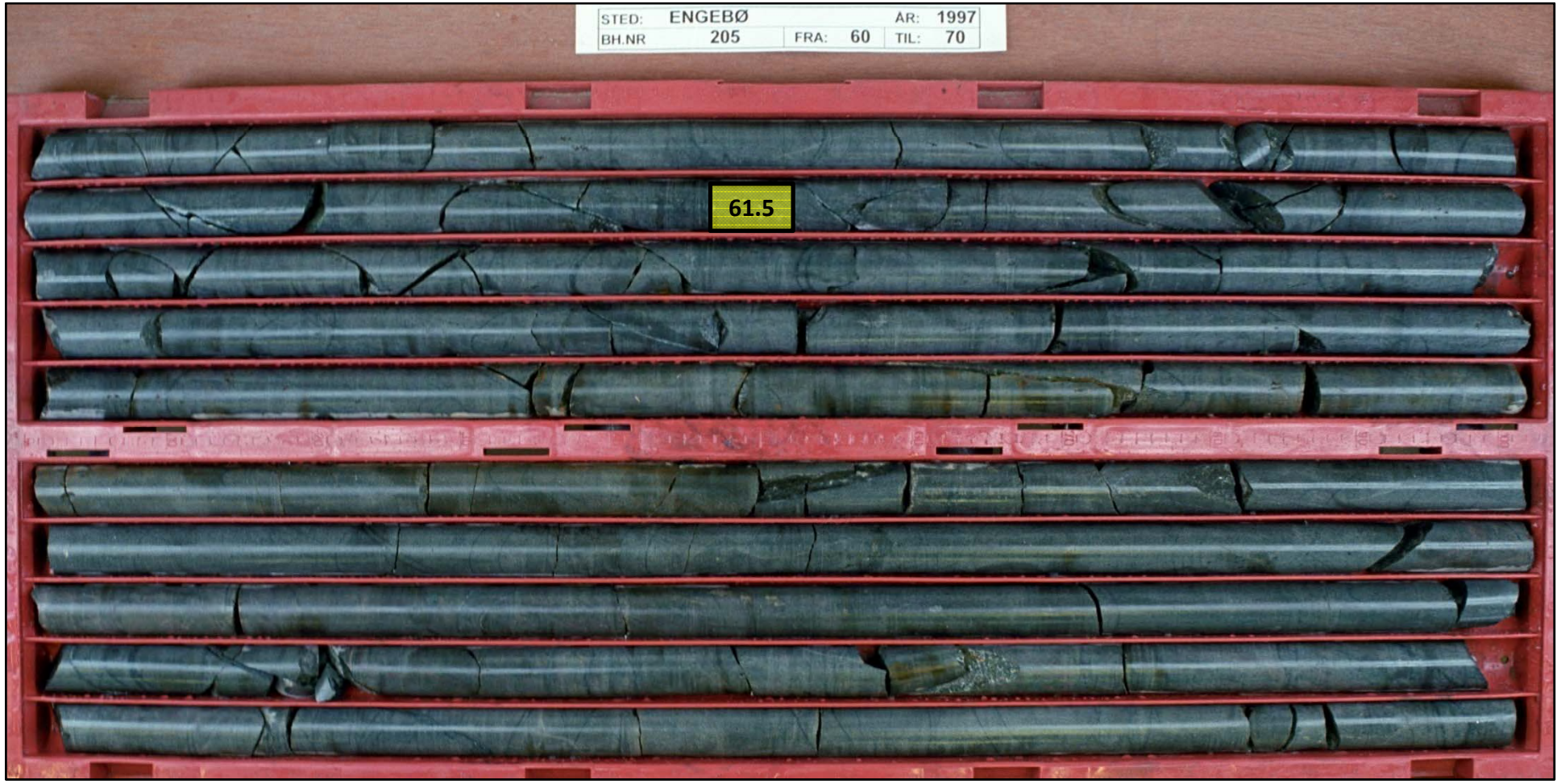
Engebøfjellet core sample information

Sample Dh205/61.5m



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; retrograde alteration along fractures; representative for a large amounts of eclogite in this part of the deposit.



Engebøfjellet, Bh205/61.5m

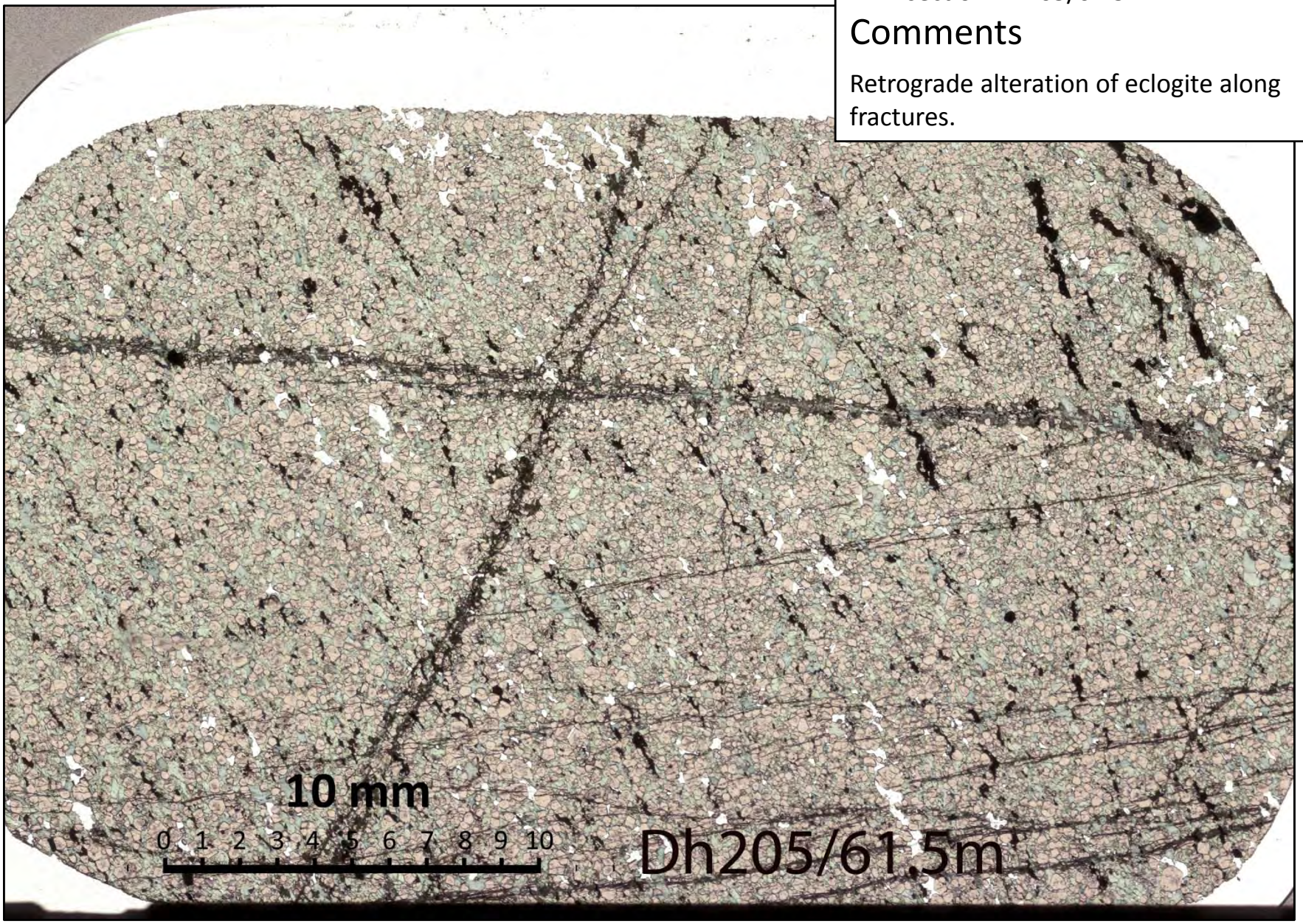
Key information

- Eclogite, amphibole-rich
- Magnetic susceptibility: 0.01245 (SI-units)
- Specific gravity: 3.56 g/cm^3
- 2.1 % TiO_2 , 19.3 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

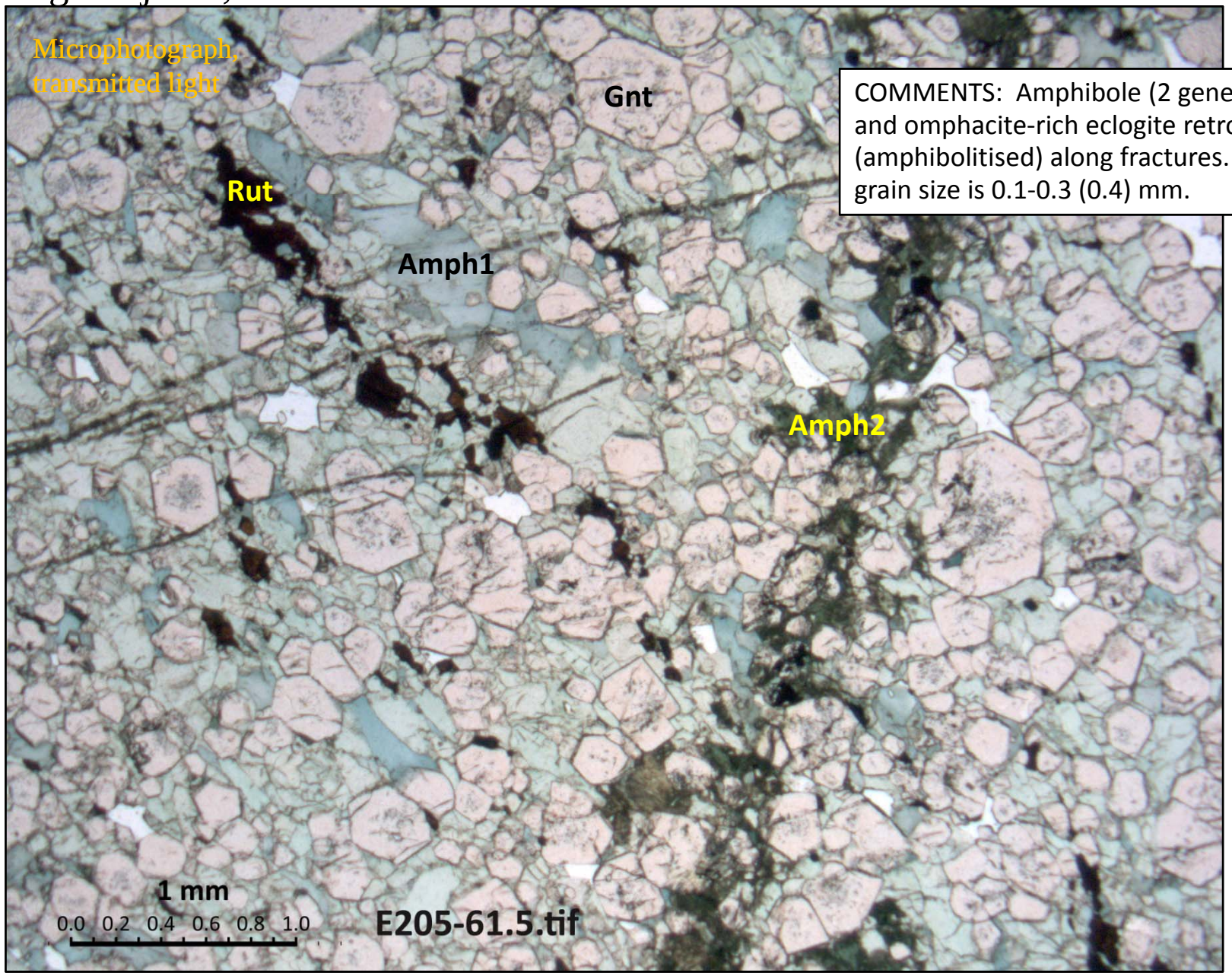
Thin-section Dh205/61.5m

Comments

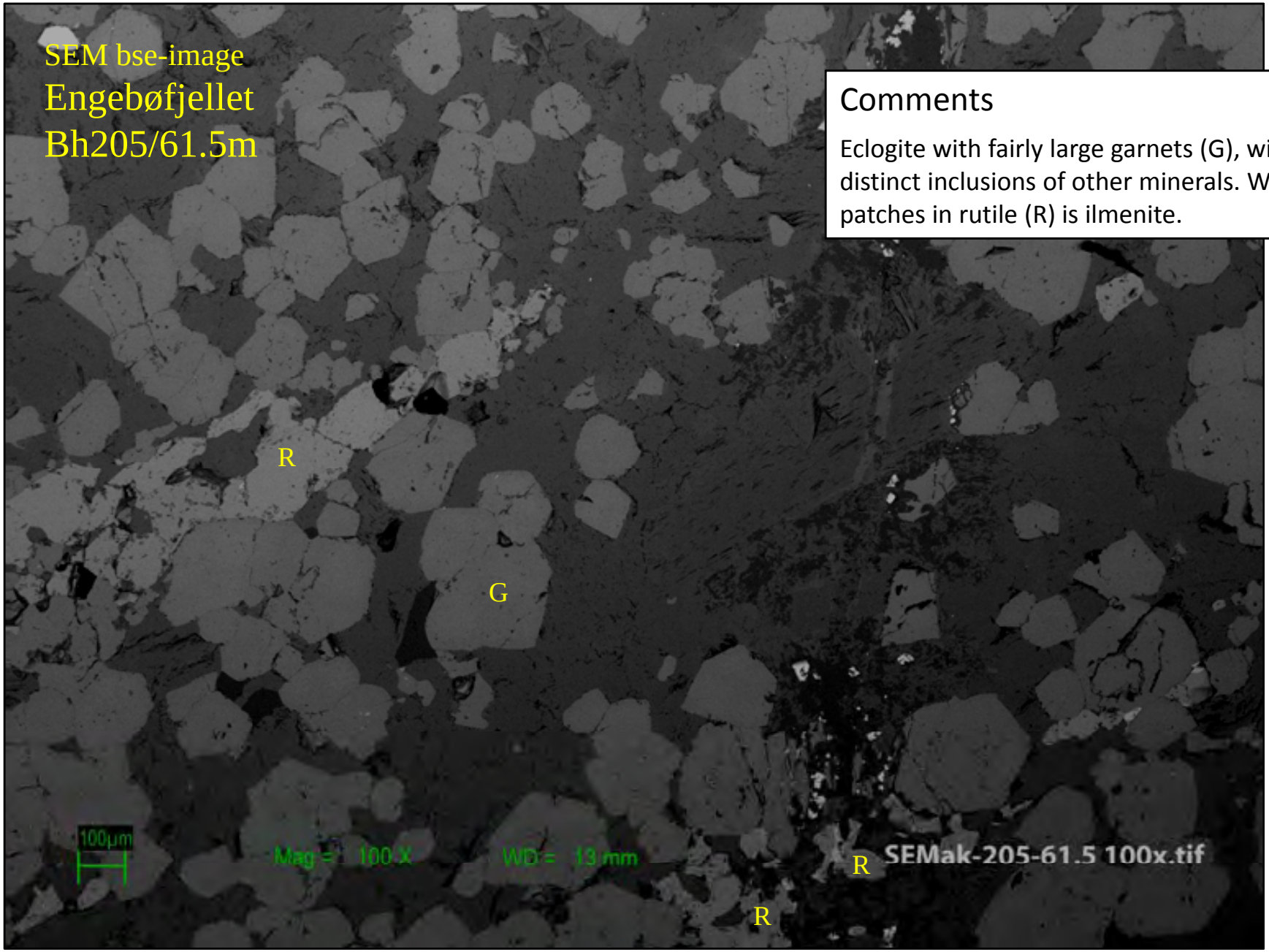
Retrograde alteration of eclogite along fractures.



Engebøfjellet, Bh205/61.5m

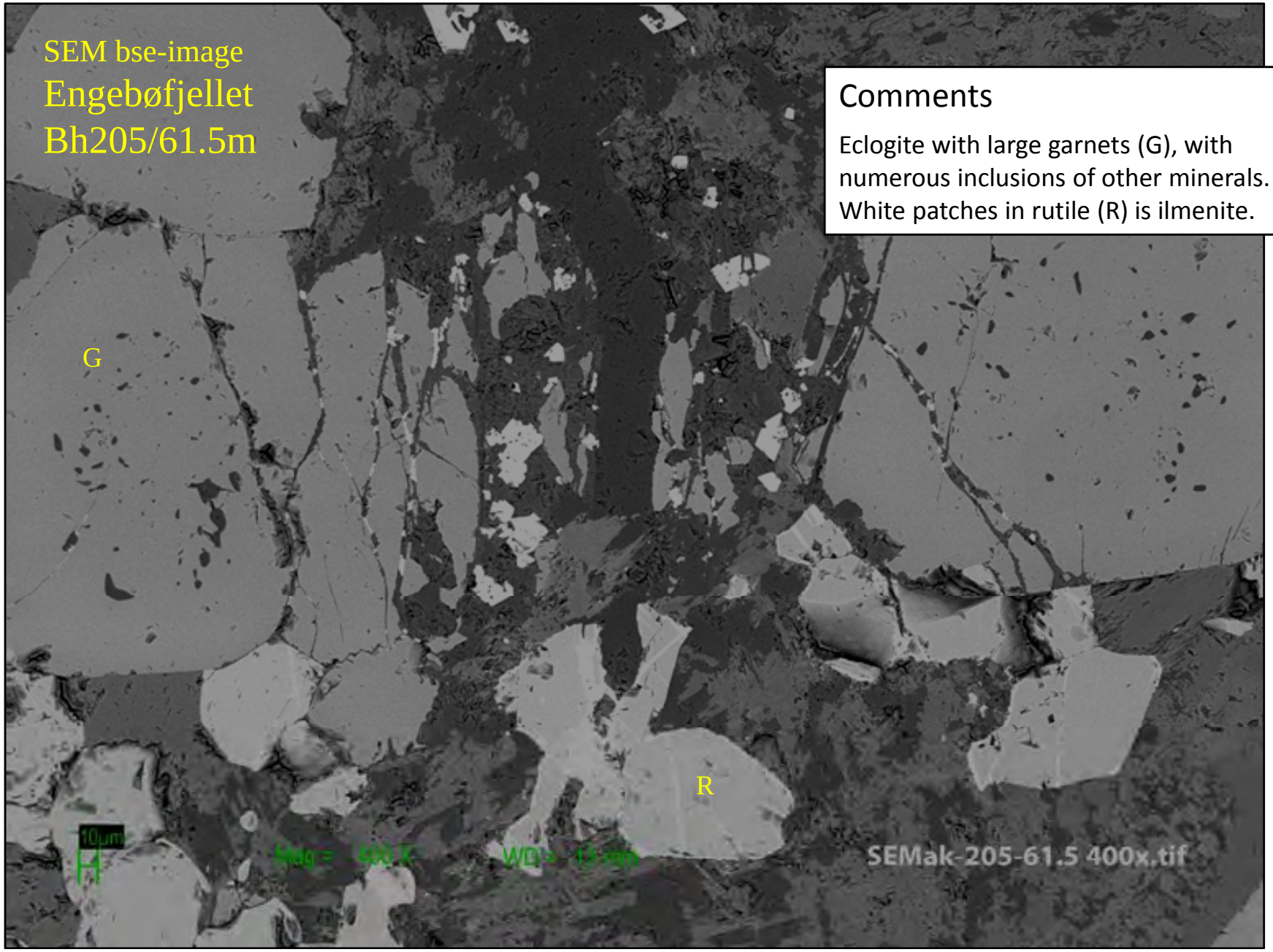


COMMENTS: Amphibole (2 generations) and omphacite-rich eclogite retrograded (amphibolitised) along fractures. Garnet grain size is 0.1-0.3 (0.4) mm.



Comments

Eclogite with fairly large garnets (G), with distinct inclusions of other minerals. White patches in rutile (R) is ilmenite.

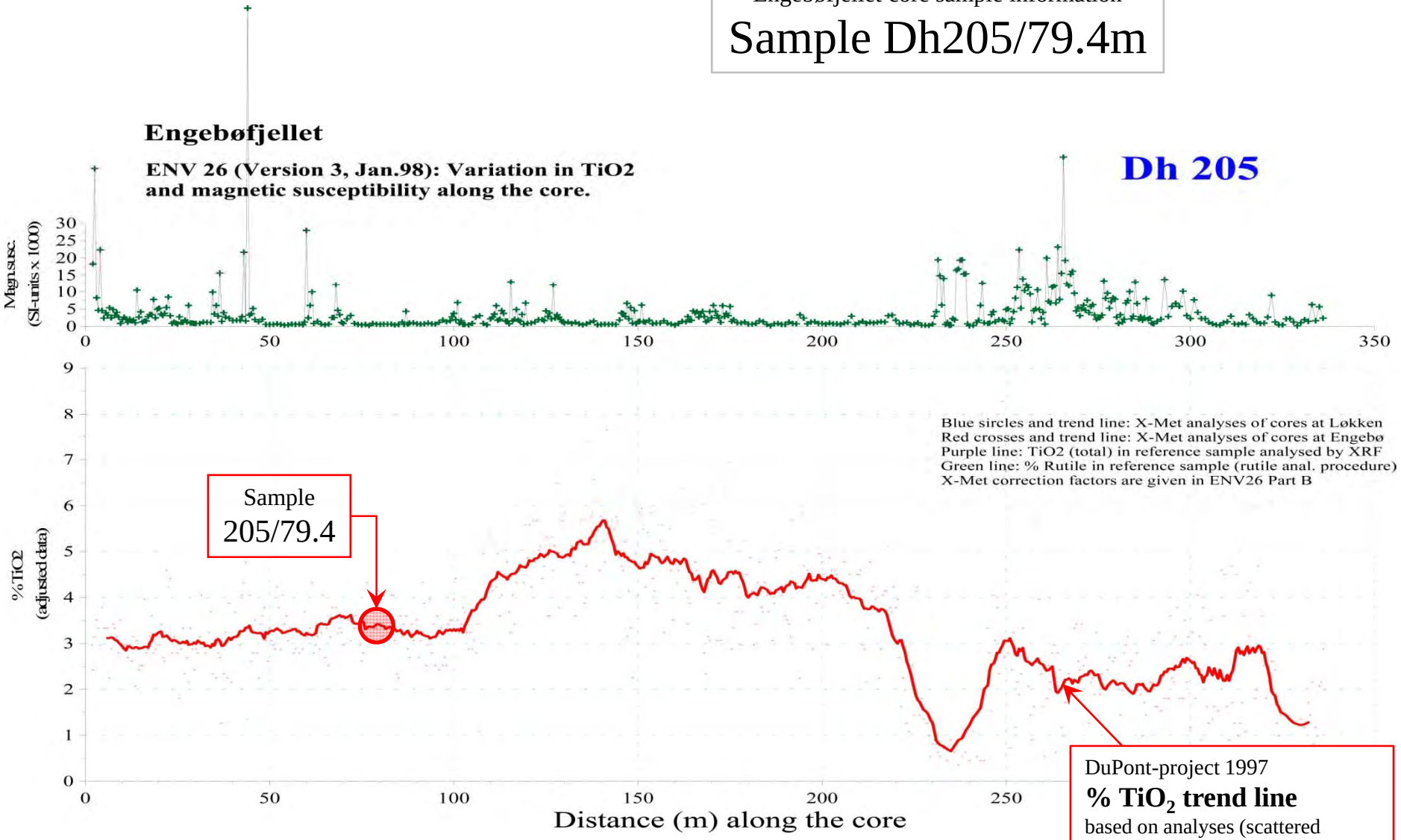


Comments

Eclogite with large garnets (G), with numerous inclusions of other minerals. White patches in rutile (R) is ilmenite.

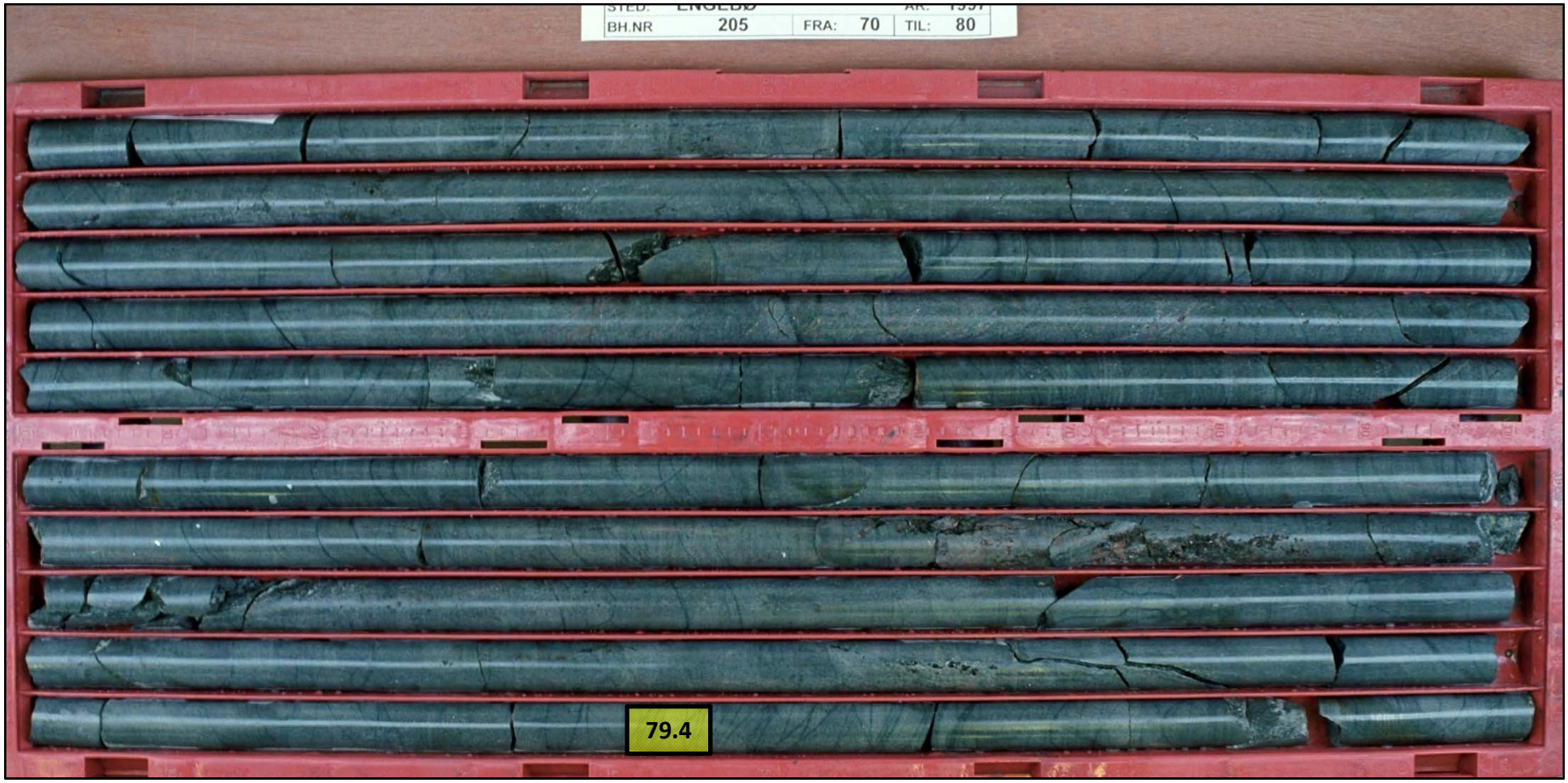
Engebøfjellet core sample information

Sample Dh205/79.4m



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; retrograde alteration along fractures; representative for a large amounts of eclogite in this part of the deposit.



Key information

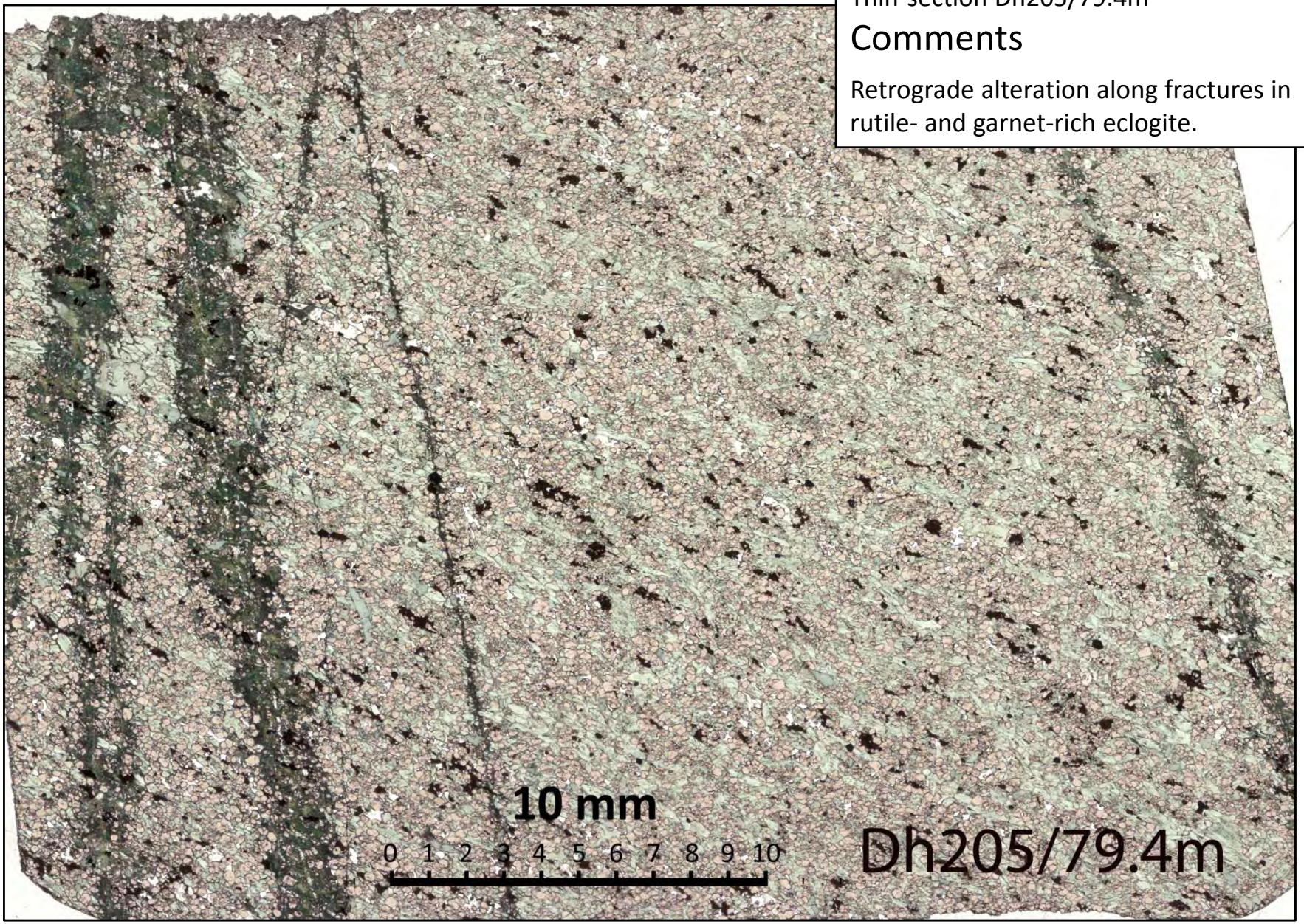
- Eclogite with retrograde fractures
- Magnetic susceptibility: 0.00138 (SI-units)
- Specific gravity: 3.55 g/cm^3
- 1.4 % TiO_2 , 17.5 % Fe_2O_3

  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

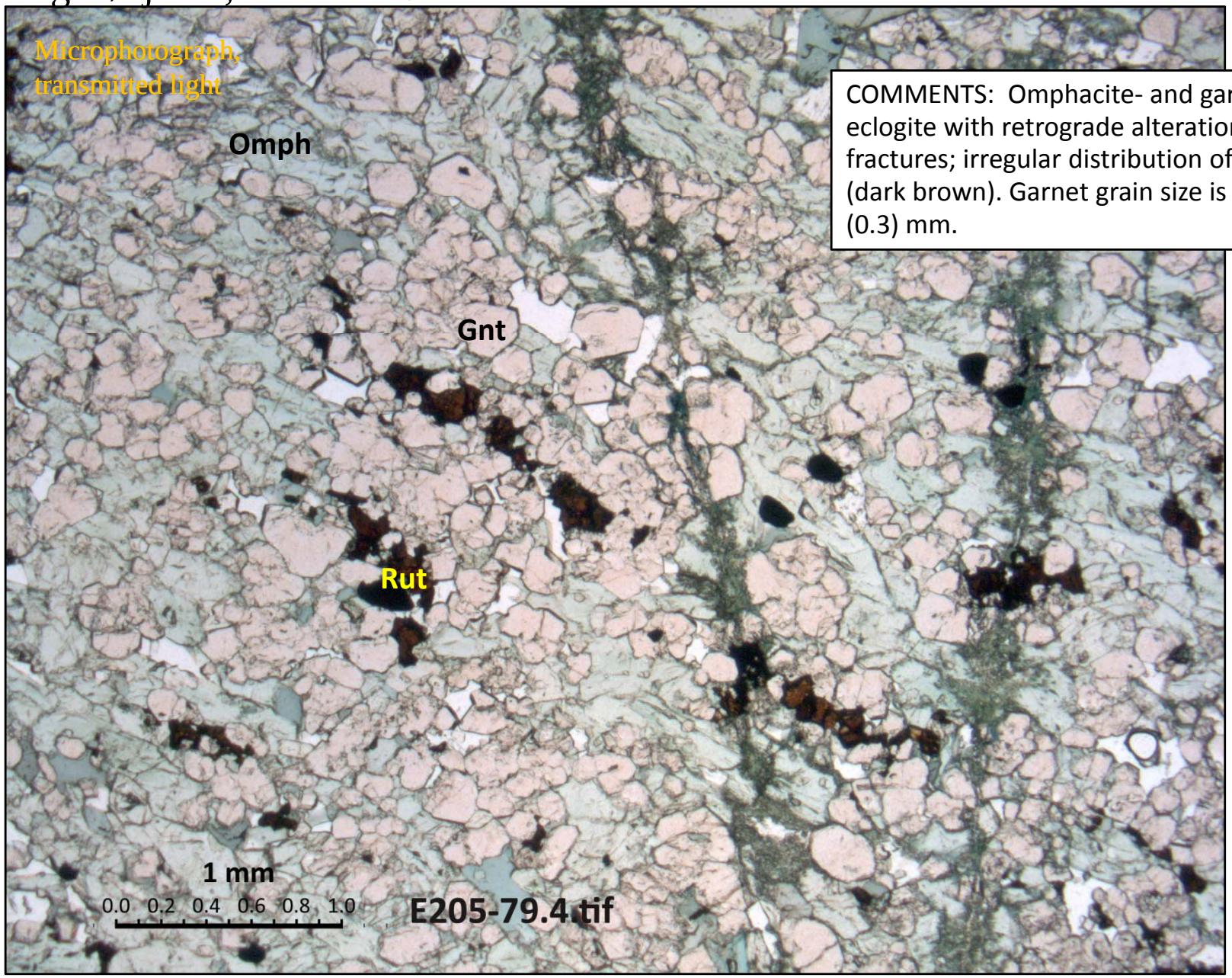
Thin-section Dh205/79.4m

Comments

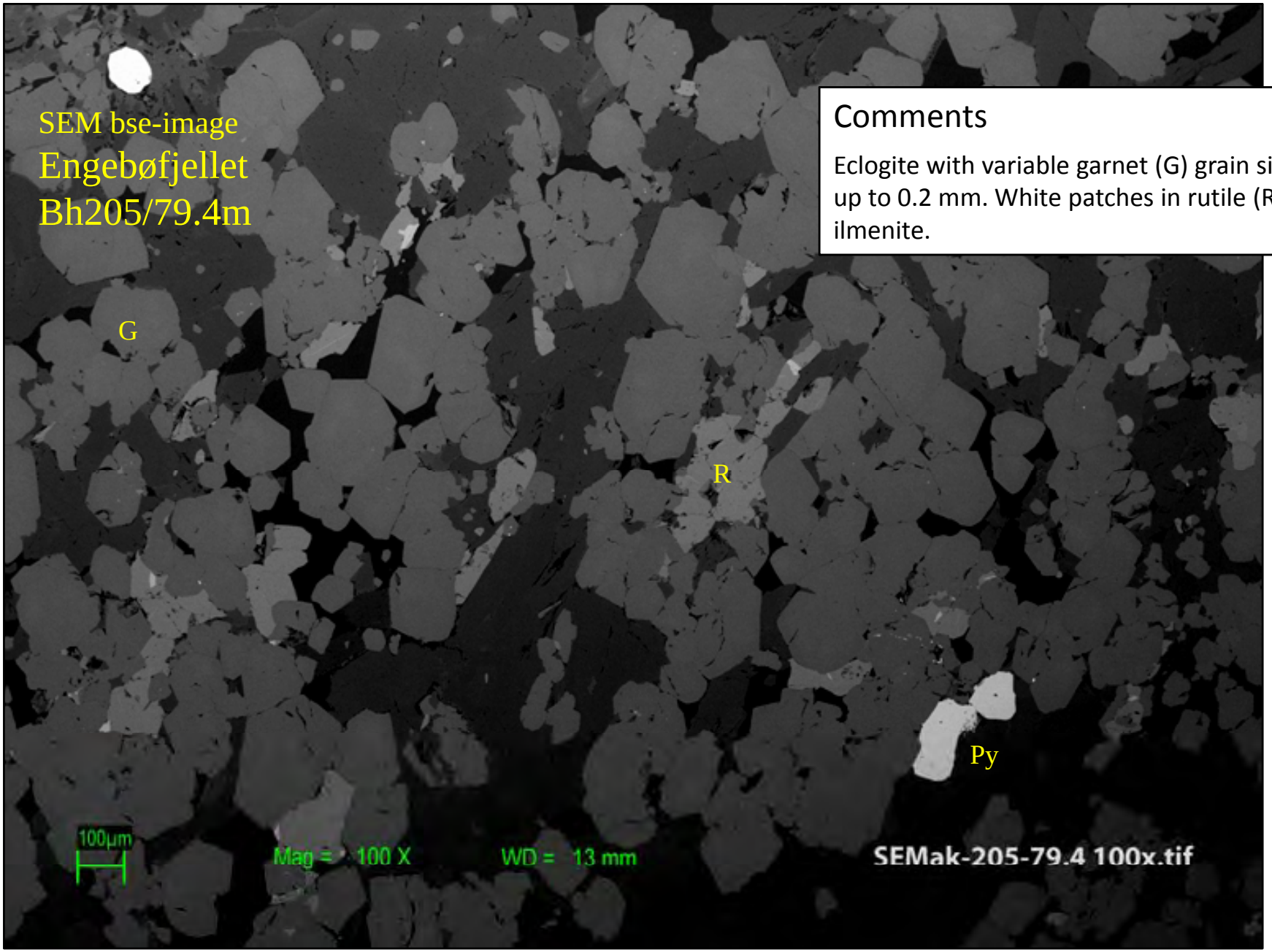
Retrograde alteration along fractures in rutile- and garnet-rich eclogite.



Engebøfjellet, Bh205/79.4m



COMMENTS: Omphacite- and garnet-rich eclogite with retrograde alteration along fractures; irregular distribution of rutile (dark brown). Garnet grain size is 0.1-0.2 (0.3) mm.

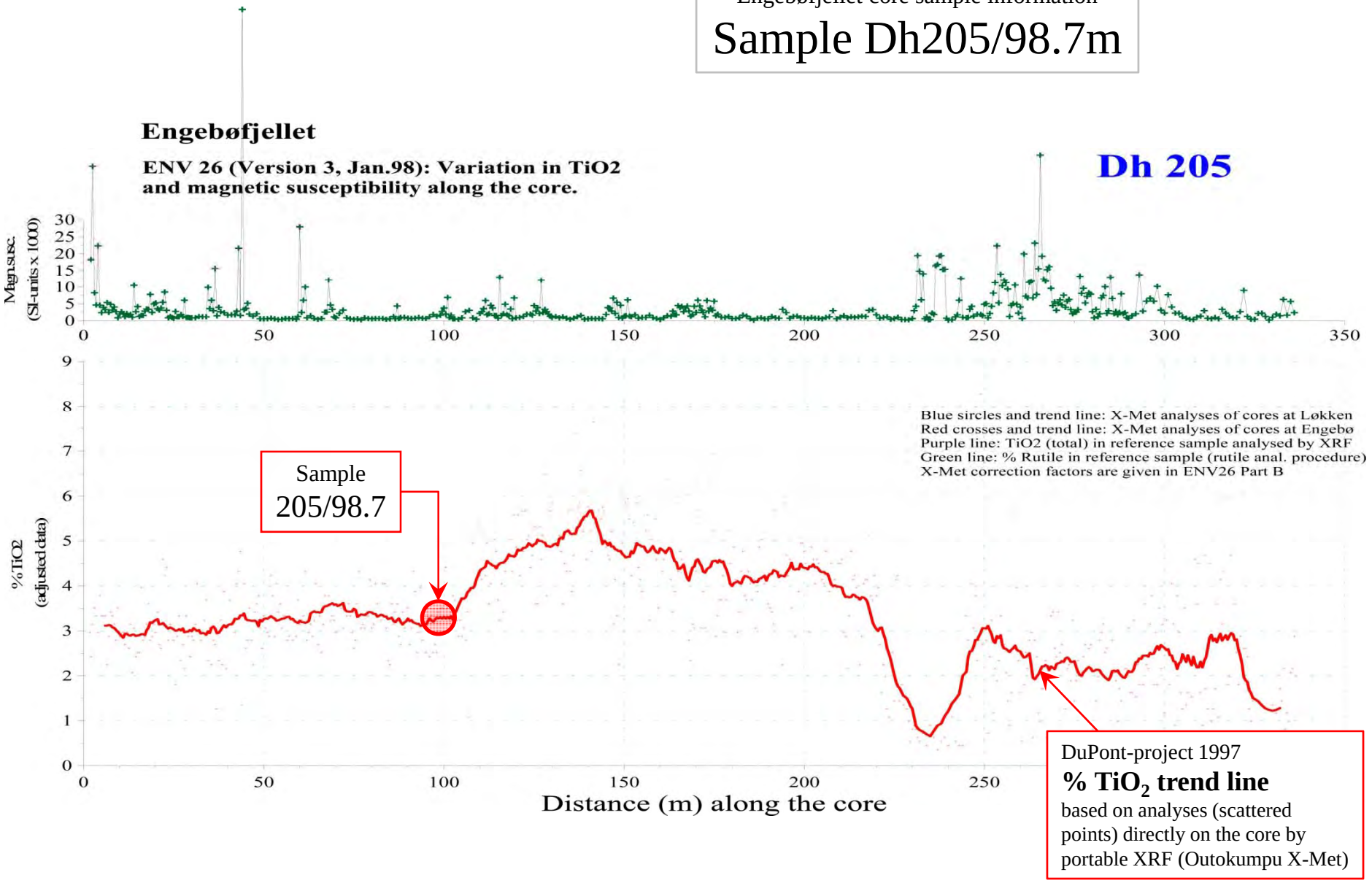


Comments

Eclogite with variable garnet (G) grain size up to 0.2 mm. White patches in rutile (R) is ilmenite.

Engebøfjellet core sample information

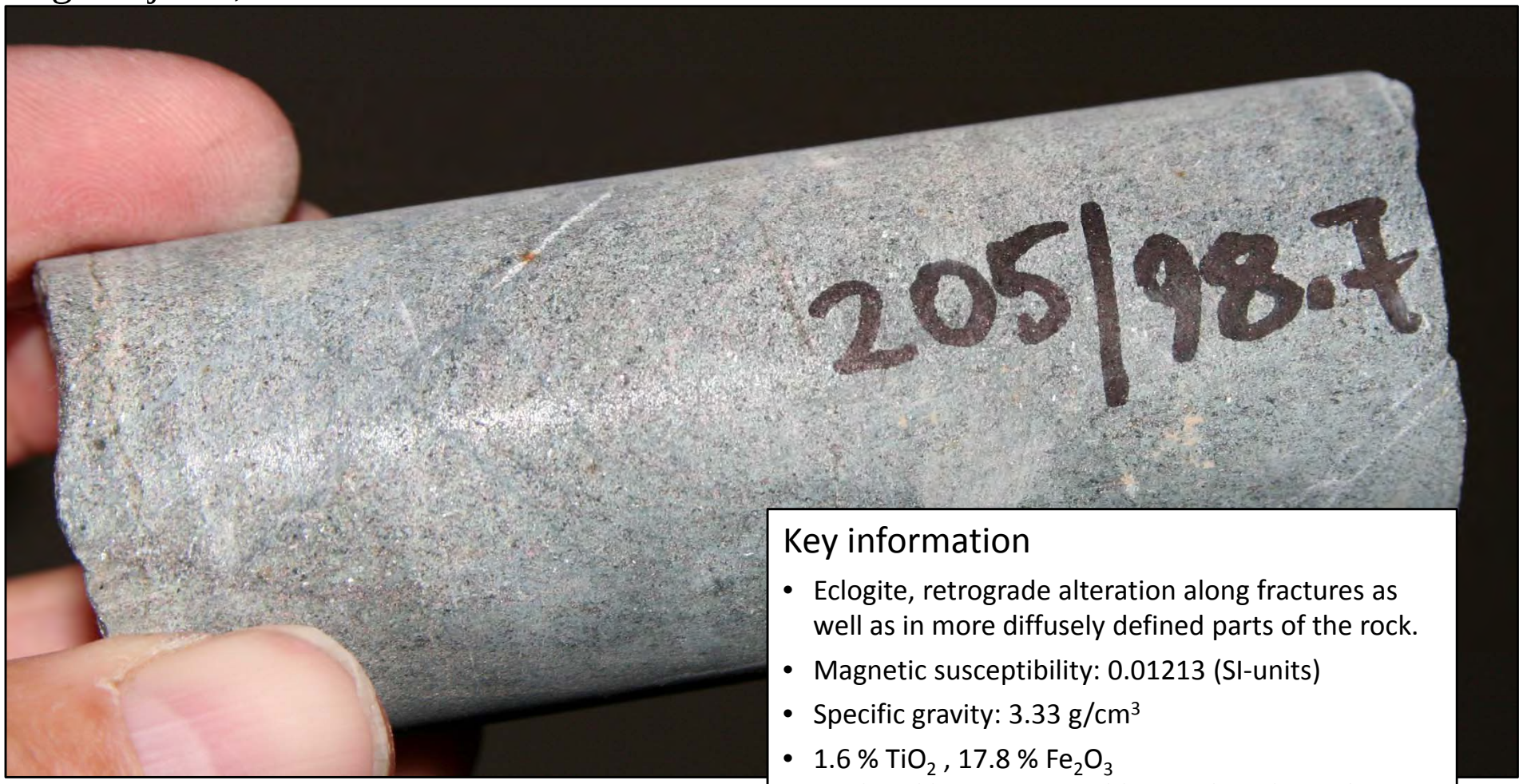
Sample Dh205/98.7m



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; retrograde alteration along fractures; representative for a large amounts of eclogite in this part of the deposit.

Engebøfjellet, Bh205/98.7m



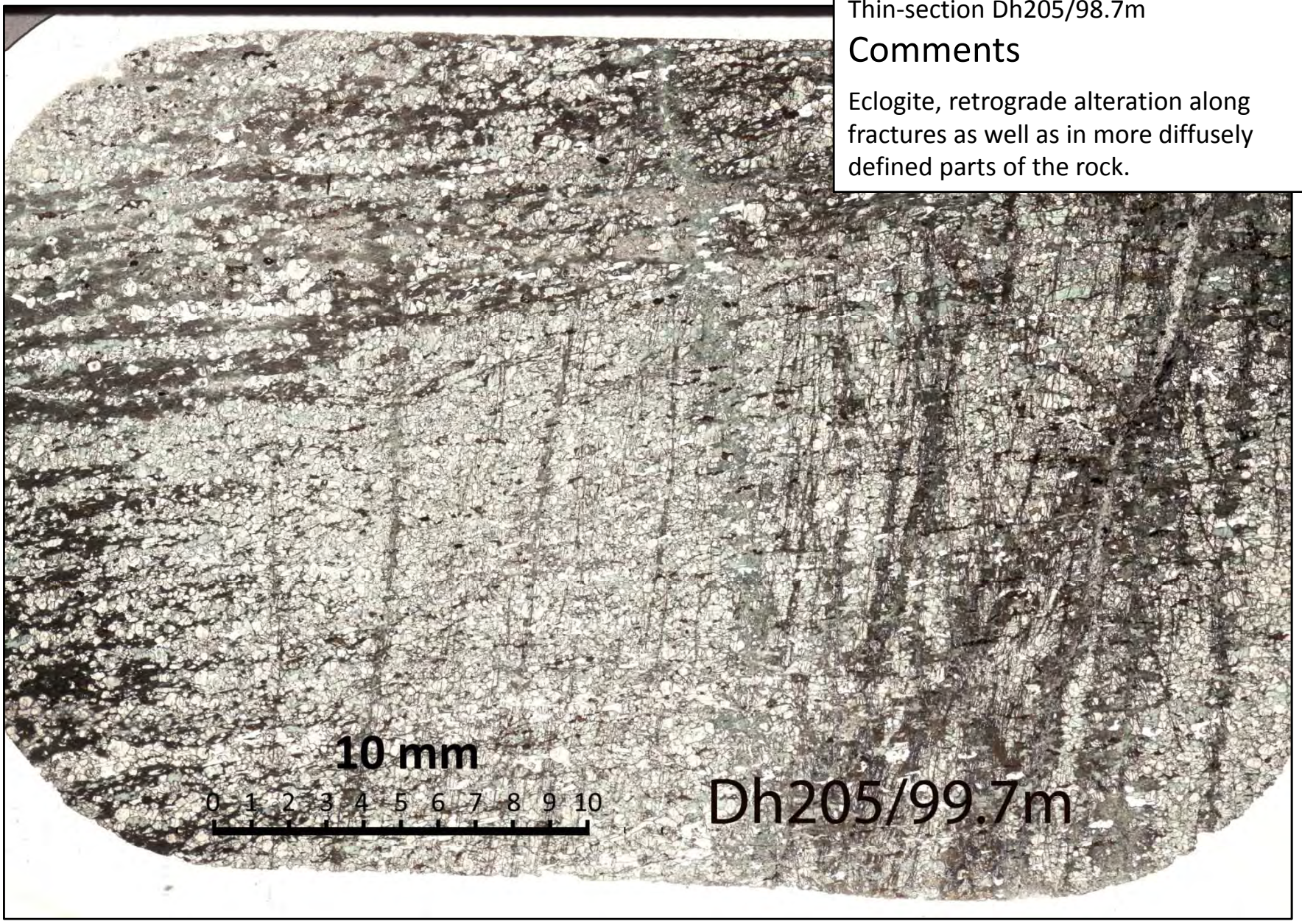
Key information

- Eclogite, retrograde alteration along fractures as well as in more diffusely defined parts of the rock.
- Magnetic susceptibility: 0.01213 (SI-units)
- Specific gravity: 3.33 g/cm^3
- 1.6 % TiO_2 , 17.8 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

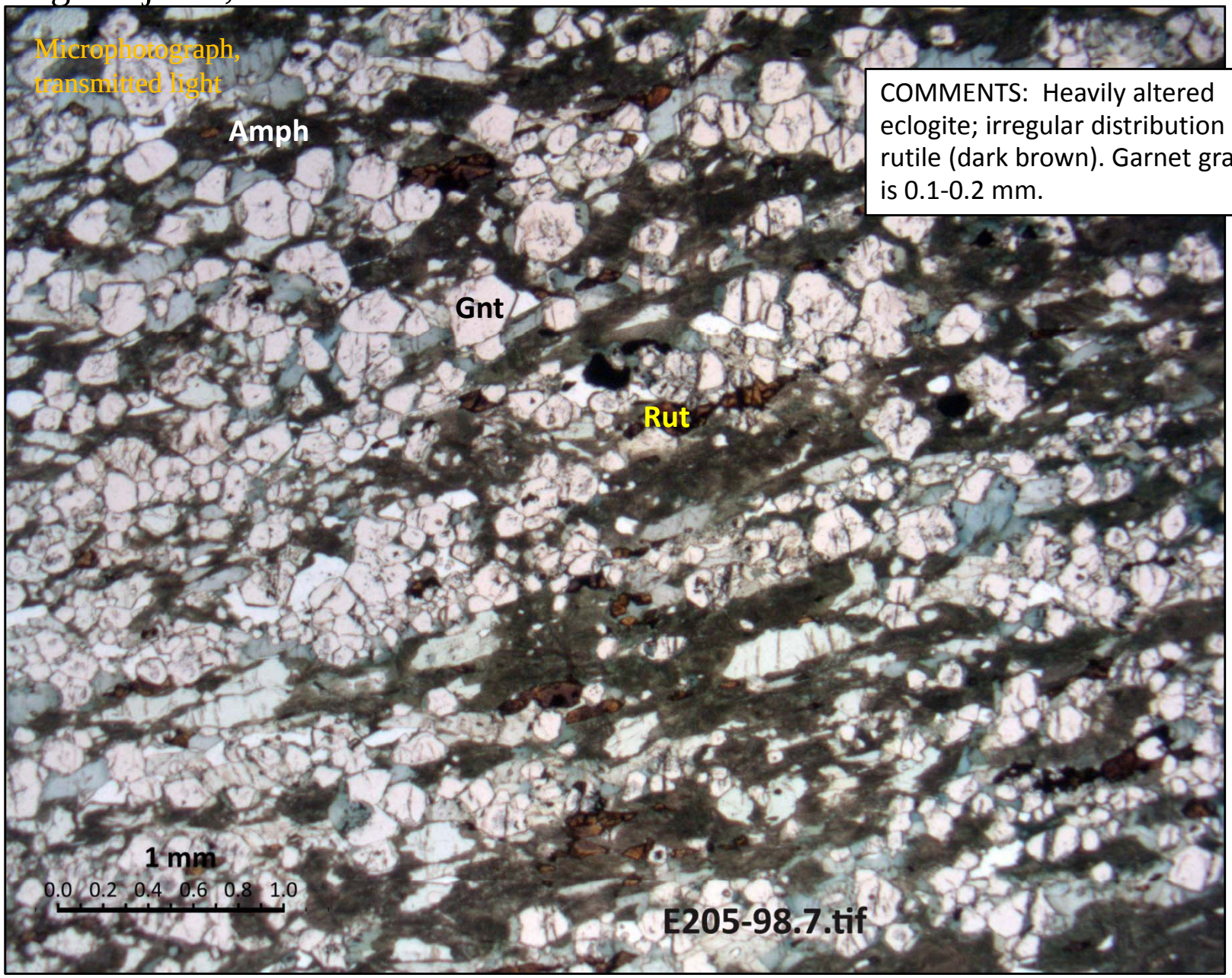
Thin-section Dh205/98.7m

Comments

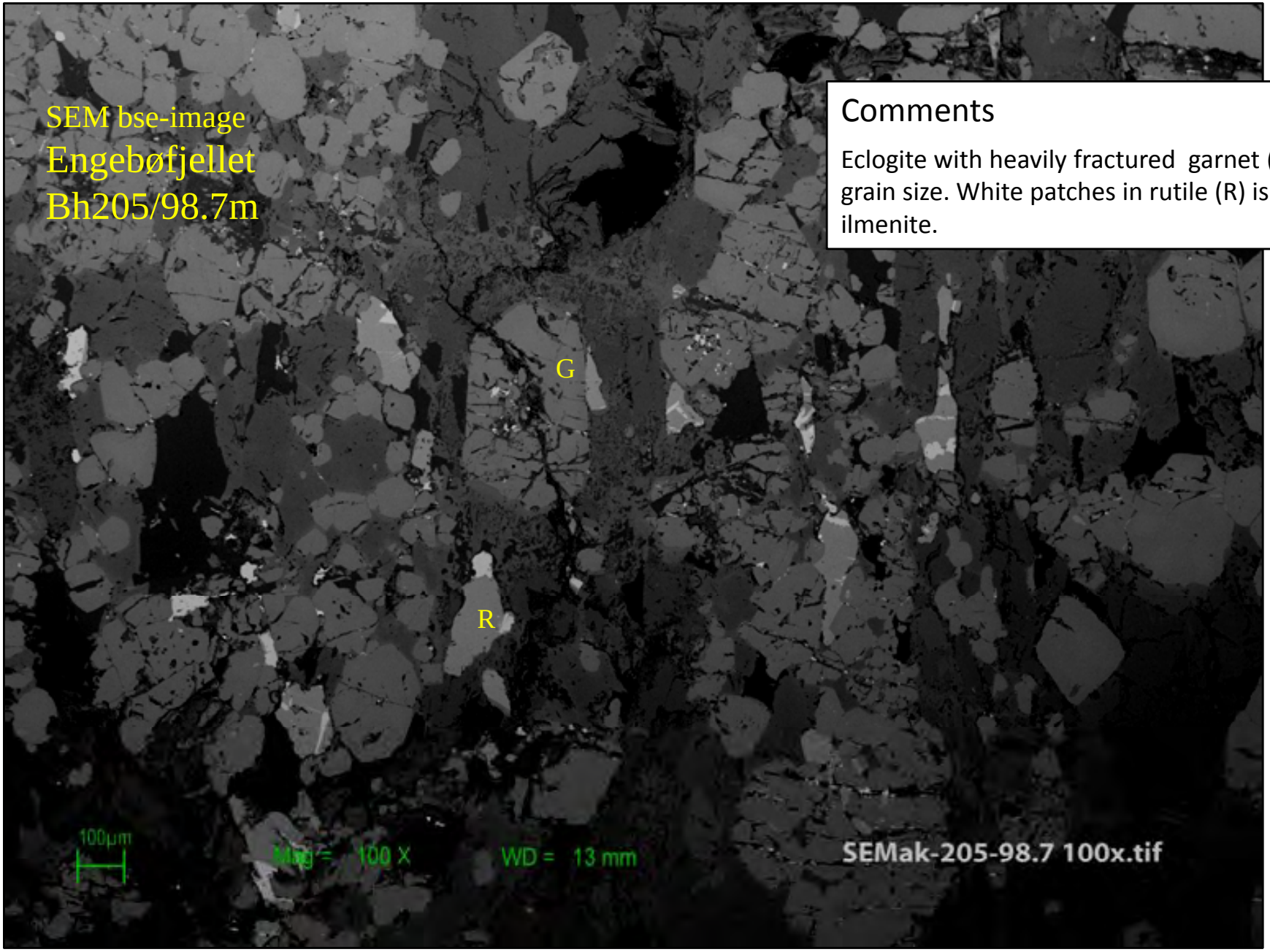
Eclogite, retrograde alteration along fractures as well as in more diffusely defined parts of the rock.



Engebøfjellet, Bh205/98.7m



COMMENTS: Heavily altered eclogite; irregular distribution of rutile (dark brown). Garnet grain size is 0.1-0.2 mm.

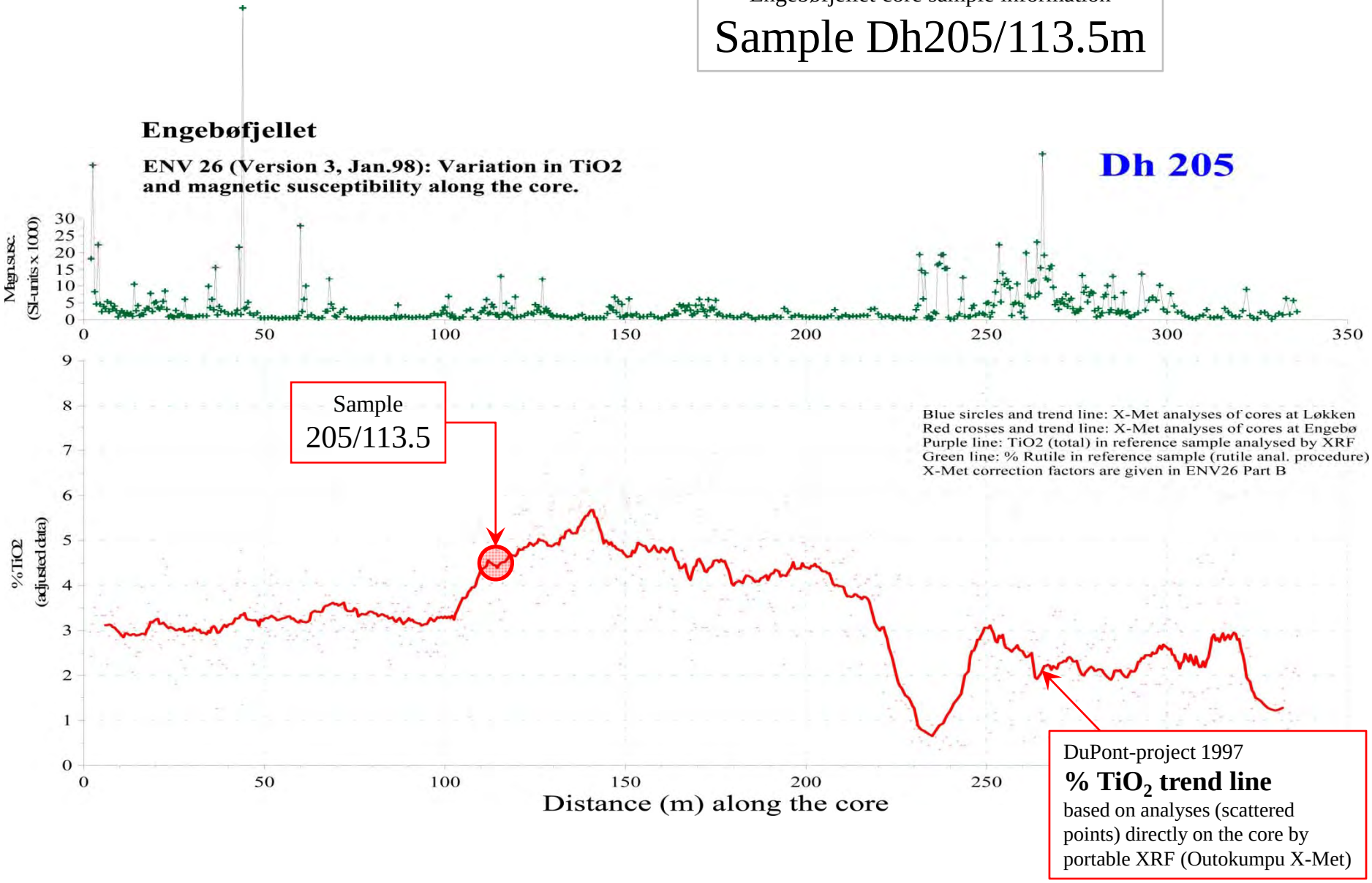


Comments

Eclogite with heavily fractured garnet (G) grain size. White patches in rutile (R) is ilmenite.

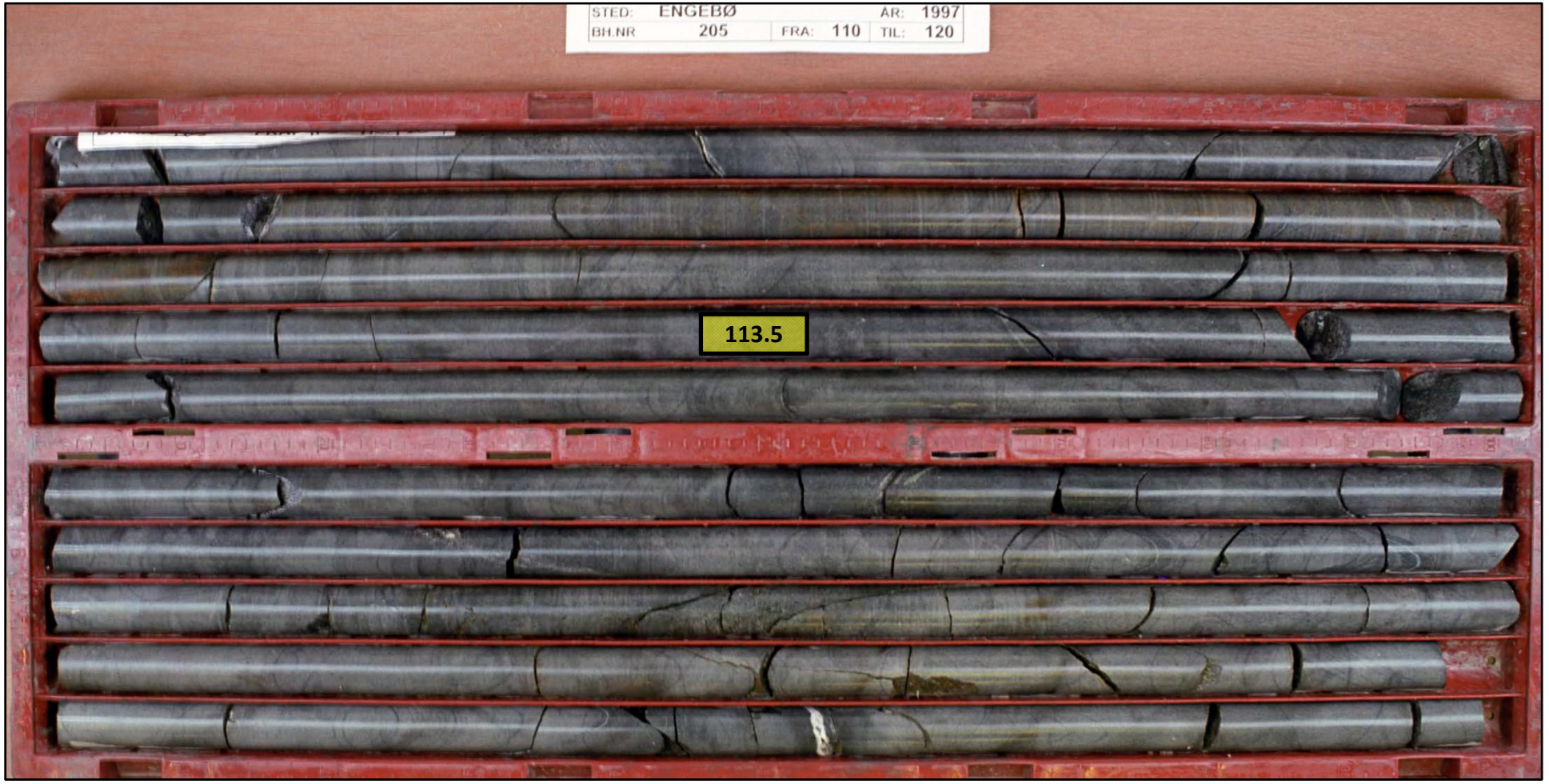
Engebøfjellet core sample information

Sample Dh205/113.5m

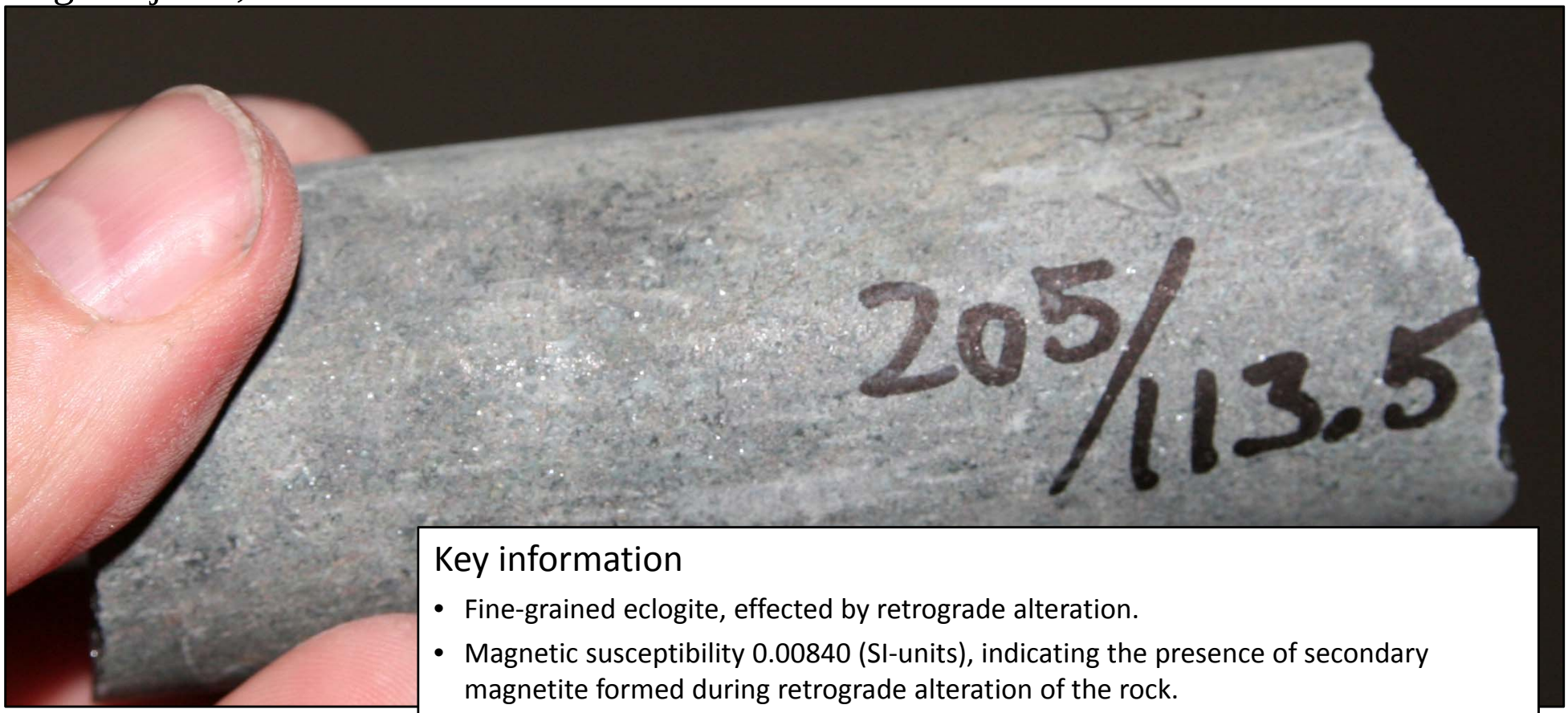


Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; distinctly and variably affected by retrograde alteration along fractures and in more diffusely defined parts.

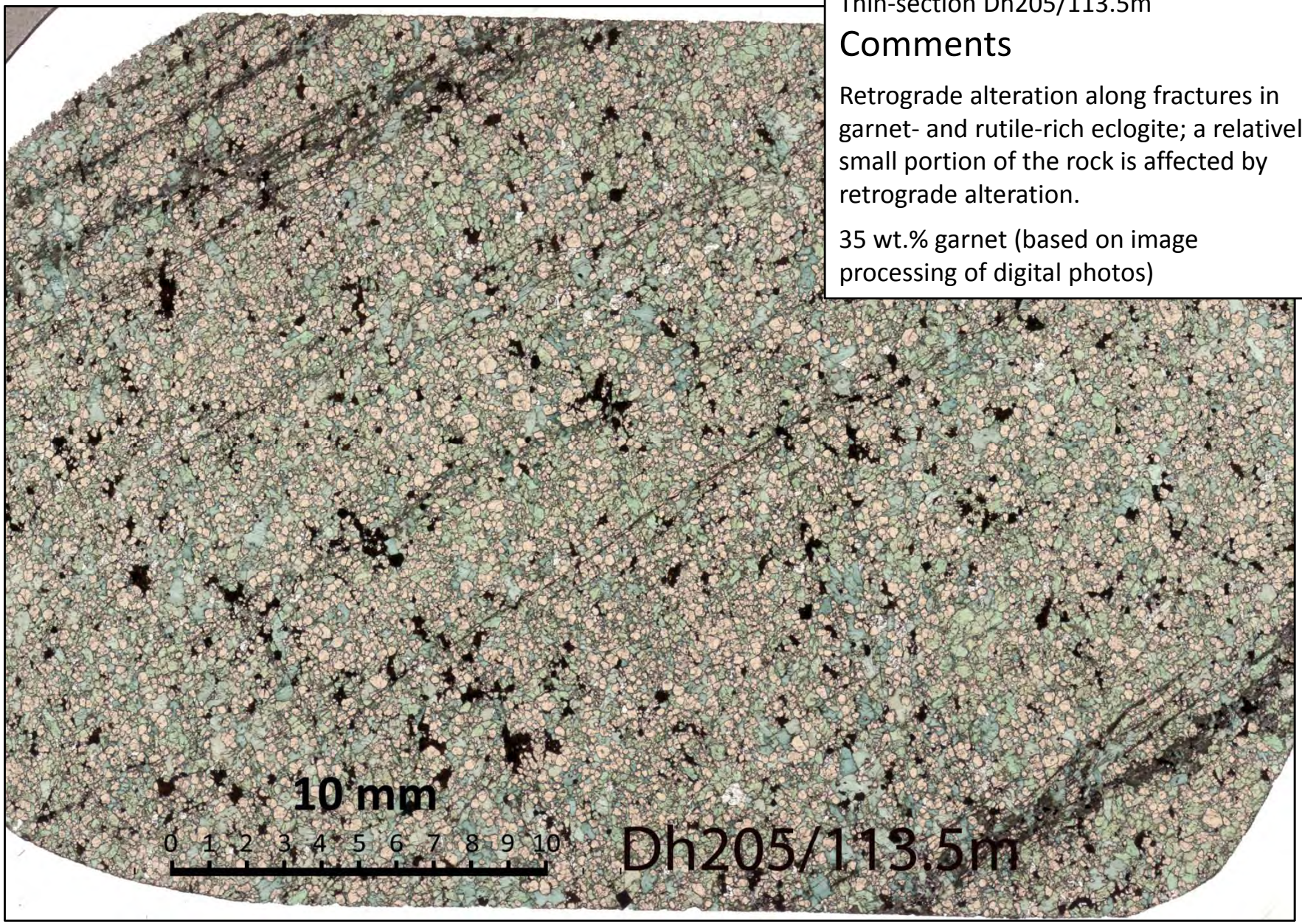


Engebøfjellet, Bh205/113.5m



Key information

- Fine-grained eclogite, effected by retrograde alteration.
- Magnetic susceptibility 0.00840 (SI-units), indicating the presence of secondary magnetite formed during retrograde alteration of the rock.
- Specific gravity: 3.53 g/cm^3
- 2.0 % TiO_2 , 20.6 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

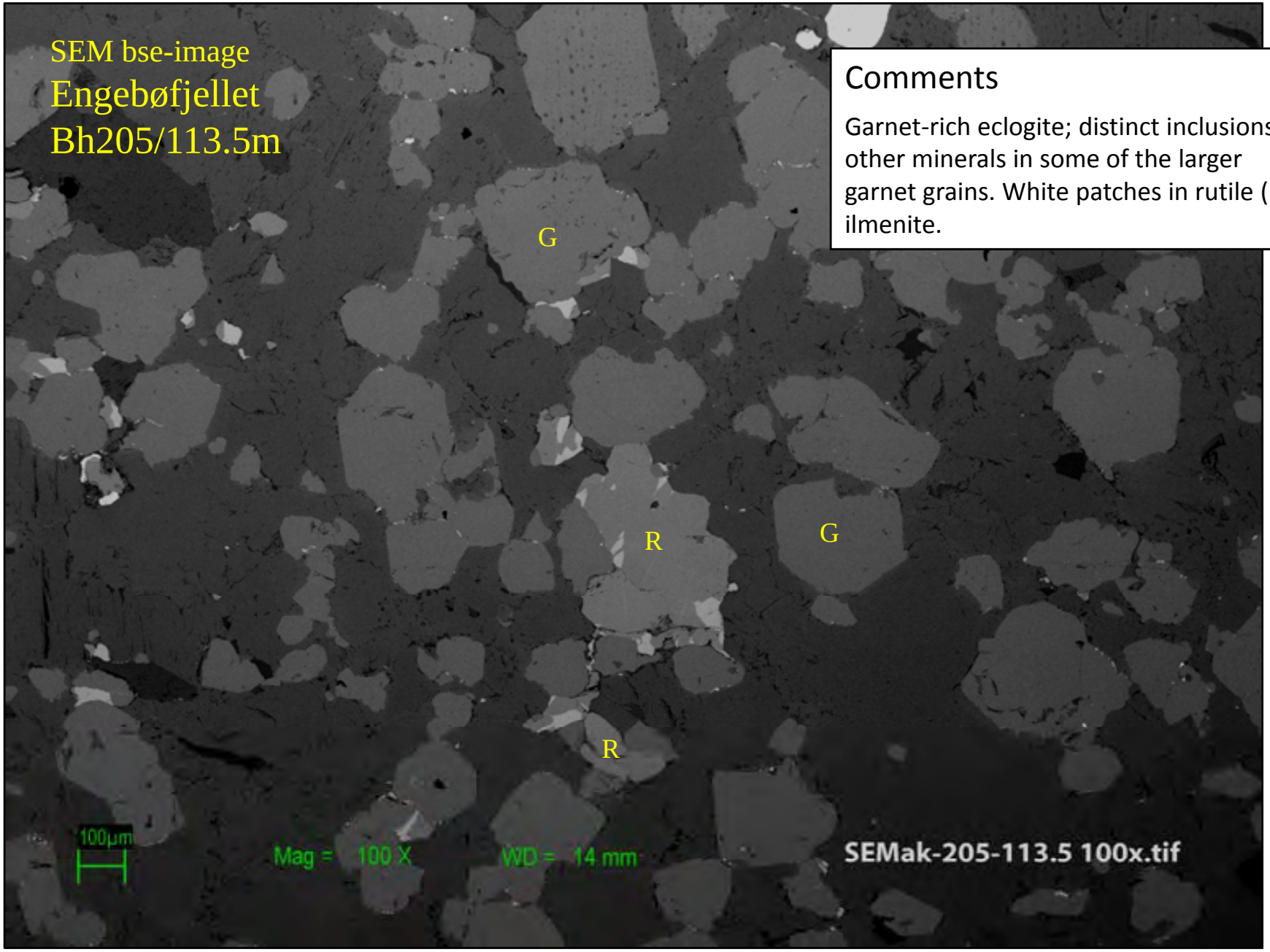


Thin-section Dh205/113.5m

Comments

Retrograde alteration along fractures in garnet- and rutile-rich eclogite; a relatively small portion of the rock is affected by retrograde alteration.

35 wt.% garnet (based on image processing of digital photos)

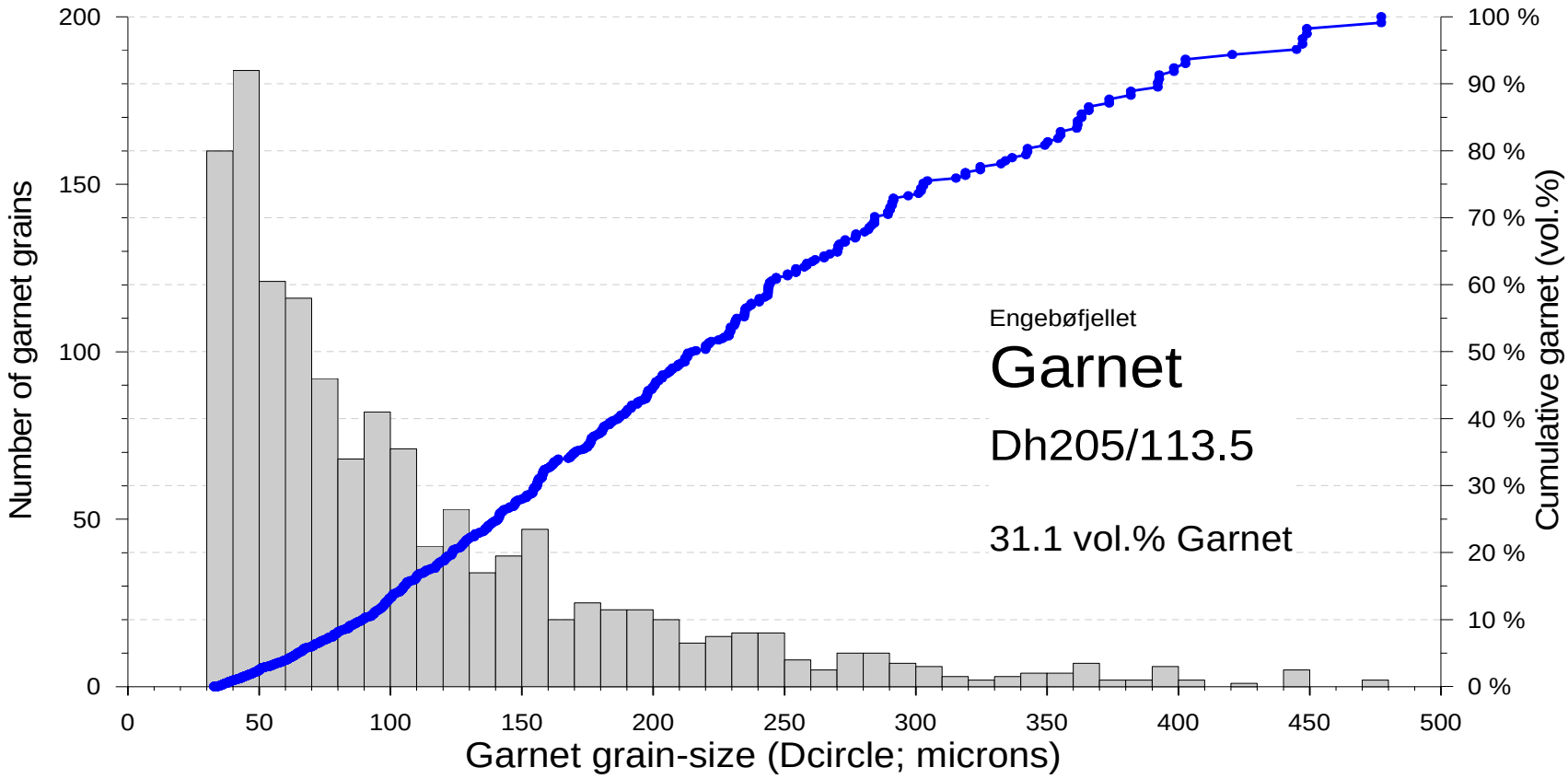


Comments

Garnet-rich eclogite; distinct inclusions of other minerals in some of the larger garnet grains. White patches in rutile (R) is ilmenite.

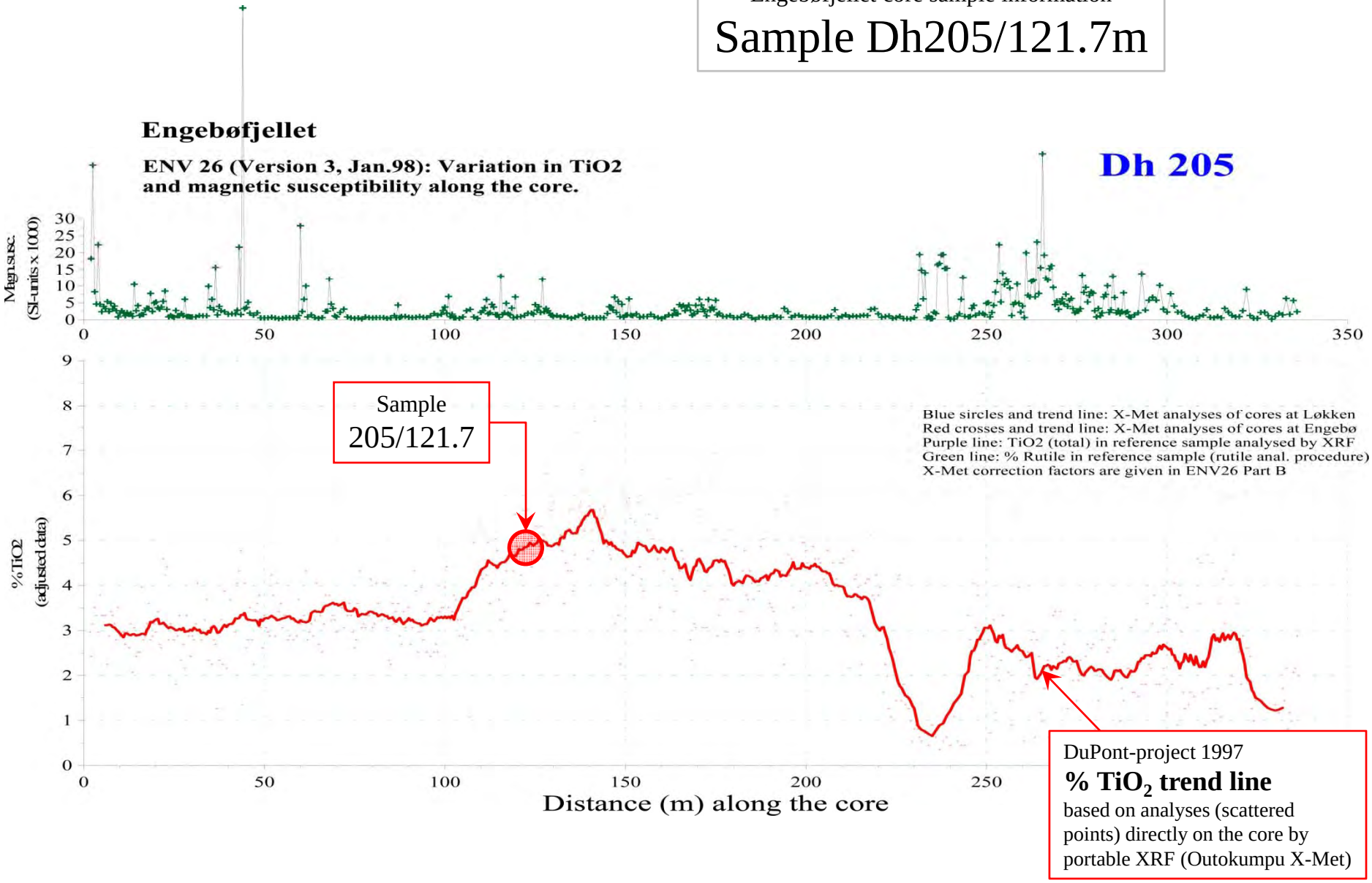
Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low, and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet is less than 220 microns. However, since grains attached to each other is registered as one larger grain by this method, the real 50 vol. % boundary is below 220 microns.



Engebøfjellet core sample information

Sample Dh205/121.7m



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; some retrograde alteration along fractures affect a minor portion of the rock; sample 205/121.7 representative for a large amounts of eclogite in this part of the deposit.

Engebøfjellet, Bh205/121.7m

Key information

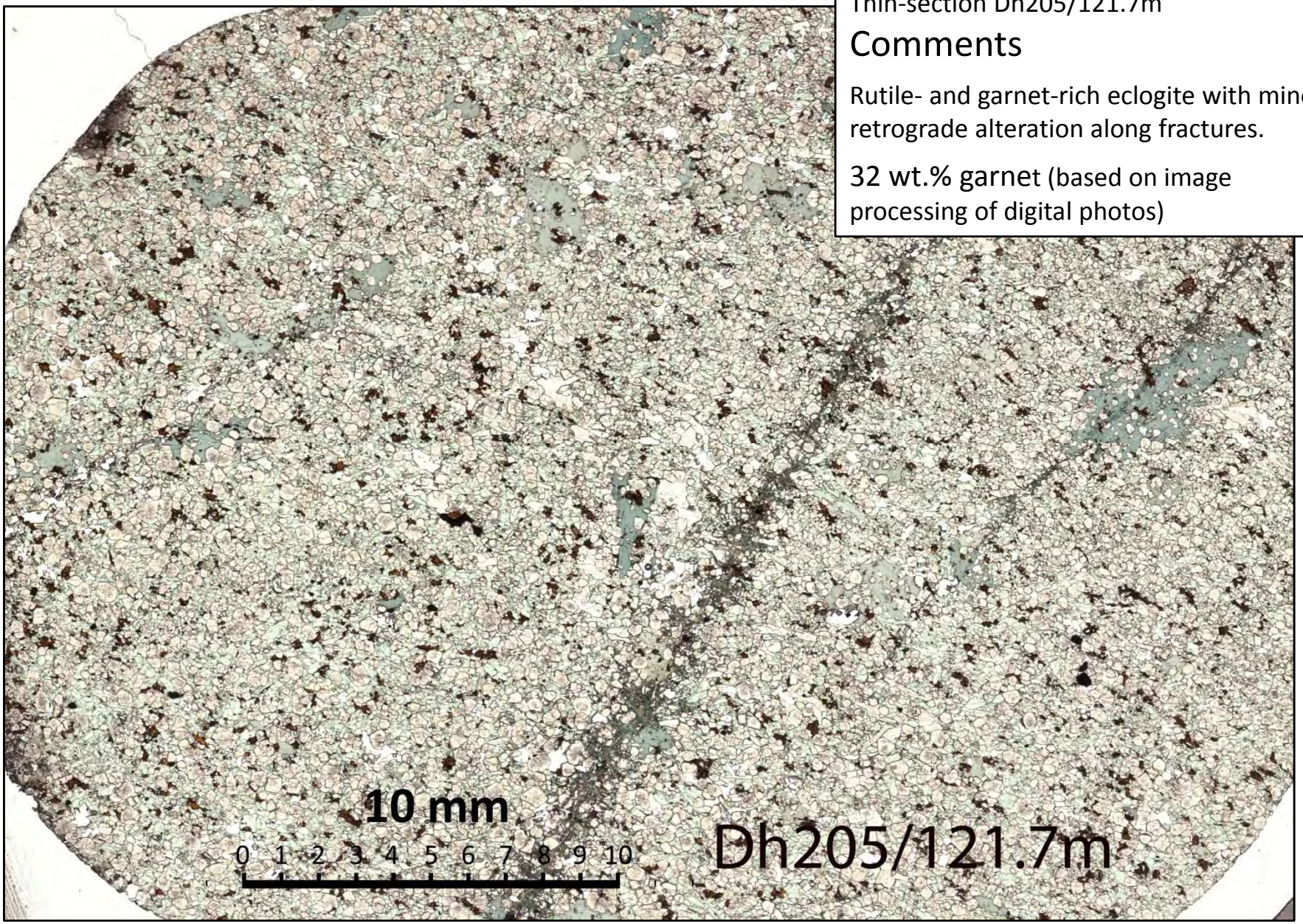
- Massive omphacite-rich eclogite with large amphibole porphyroblasts (dark green patches).
- Magnetic susceptibility: 0.00087 (SI-units)
- Specific gravity: 3.52 g/cm^3

Thin-section Dh205/121.7m

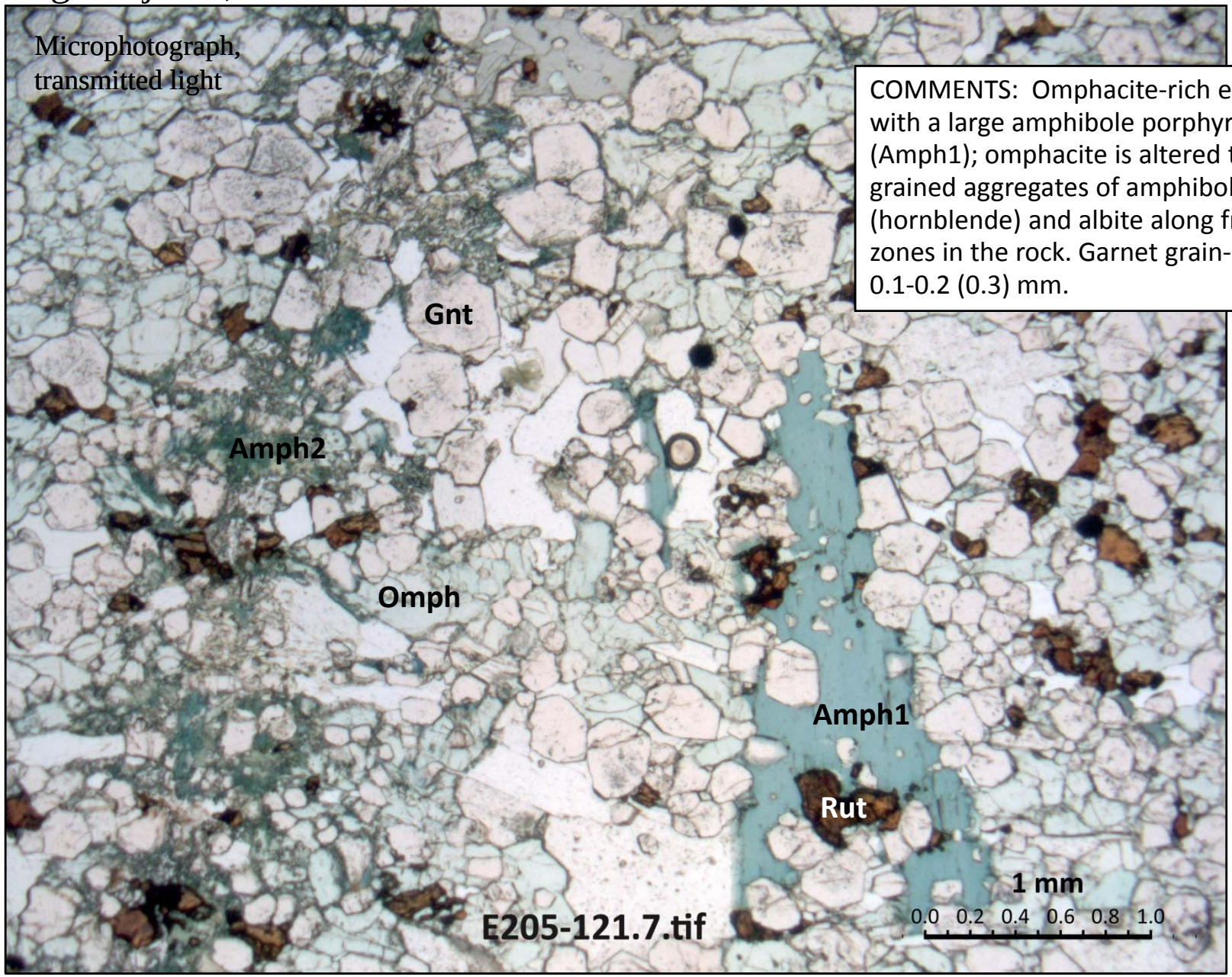
Comments

Rutile- and garnet-rich eclogite with minor retrograde alteration along fractures.

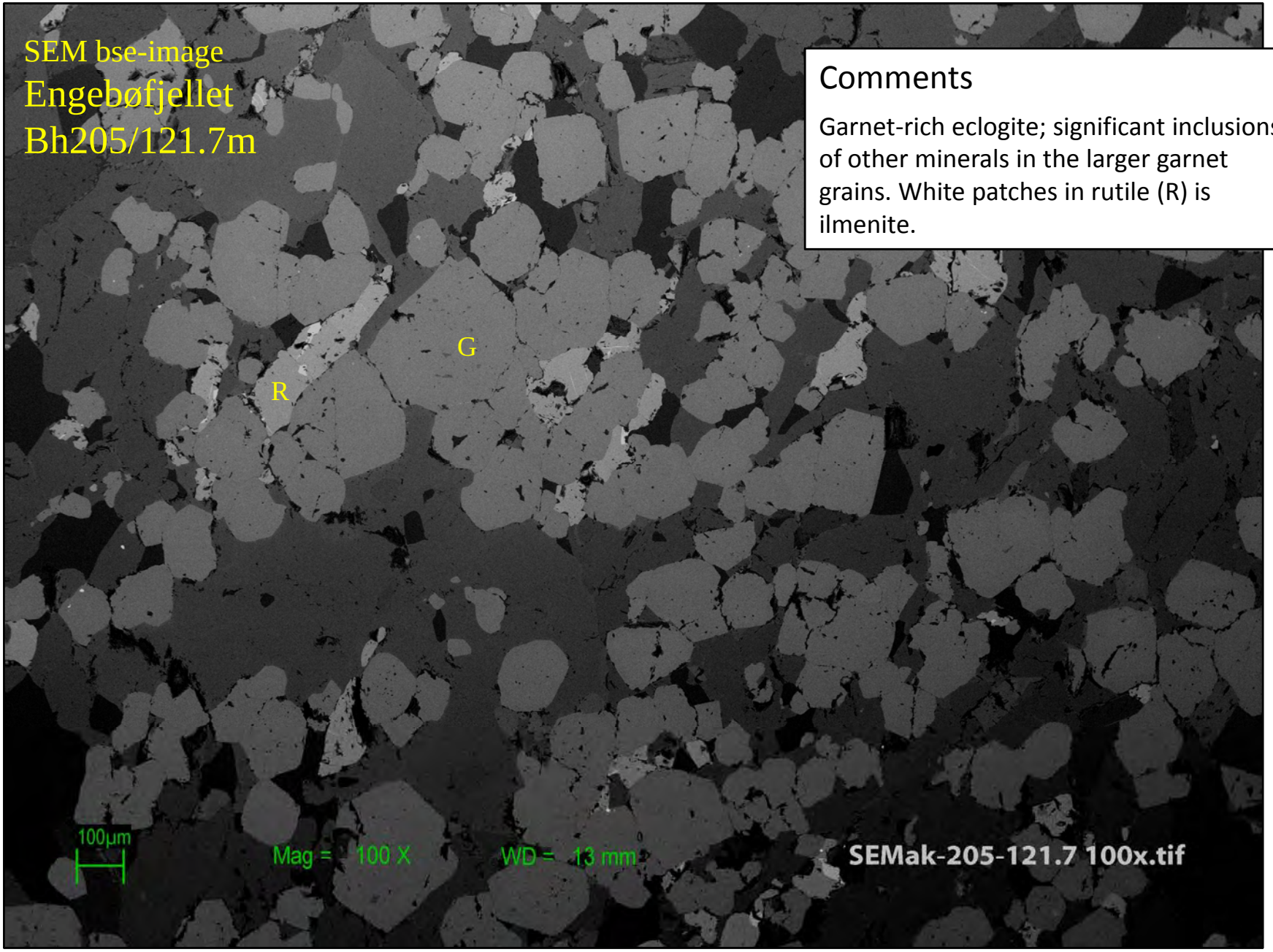
32 wt.% garnet (based on image processing of digital photos)



Engebøfjellet, Bh205/121.7m



COMMENTS: Omphacite-rich eclogite with a large amphibole porphyroblasts (Amph1); omphacite is altered to fine-grained aggregates of amphibole (hornblende) and albite along fracture zones in the rock. Garnet grain-size is 0.1-0.2 (0.3) mm.

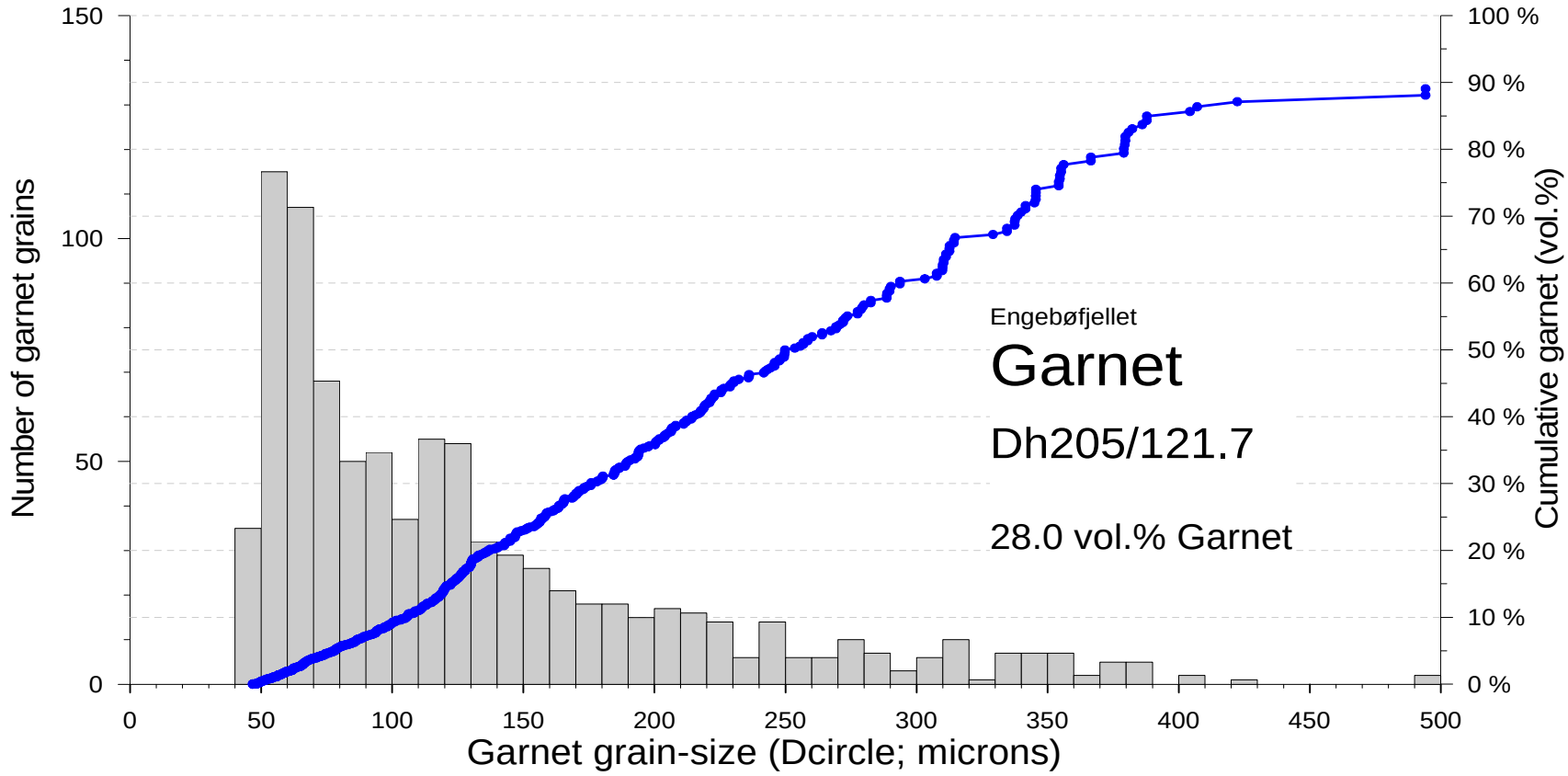


Comments

Garnet-rich eclogite; significant inclusions of other minerals in the larger garnet grains. White patches in rutile (R) is ilmenite.

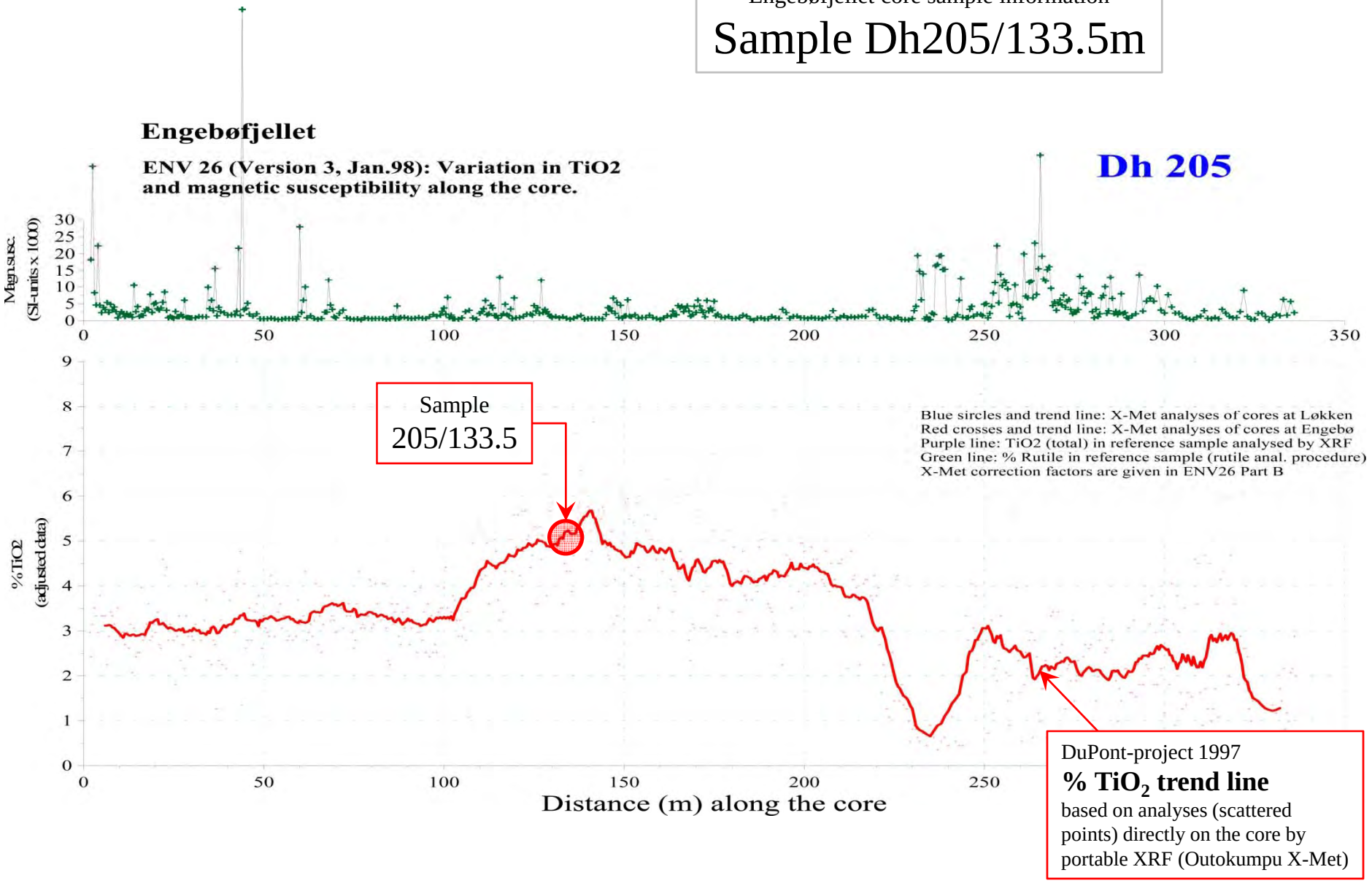
Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low, and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet is less than 250 microns. However, since grains attached to each other is registered as one larger grain by this method, the real 50 vol. % boundary is below 250 microns.



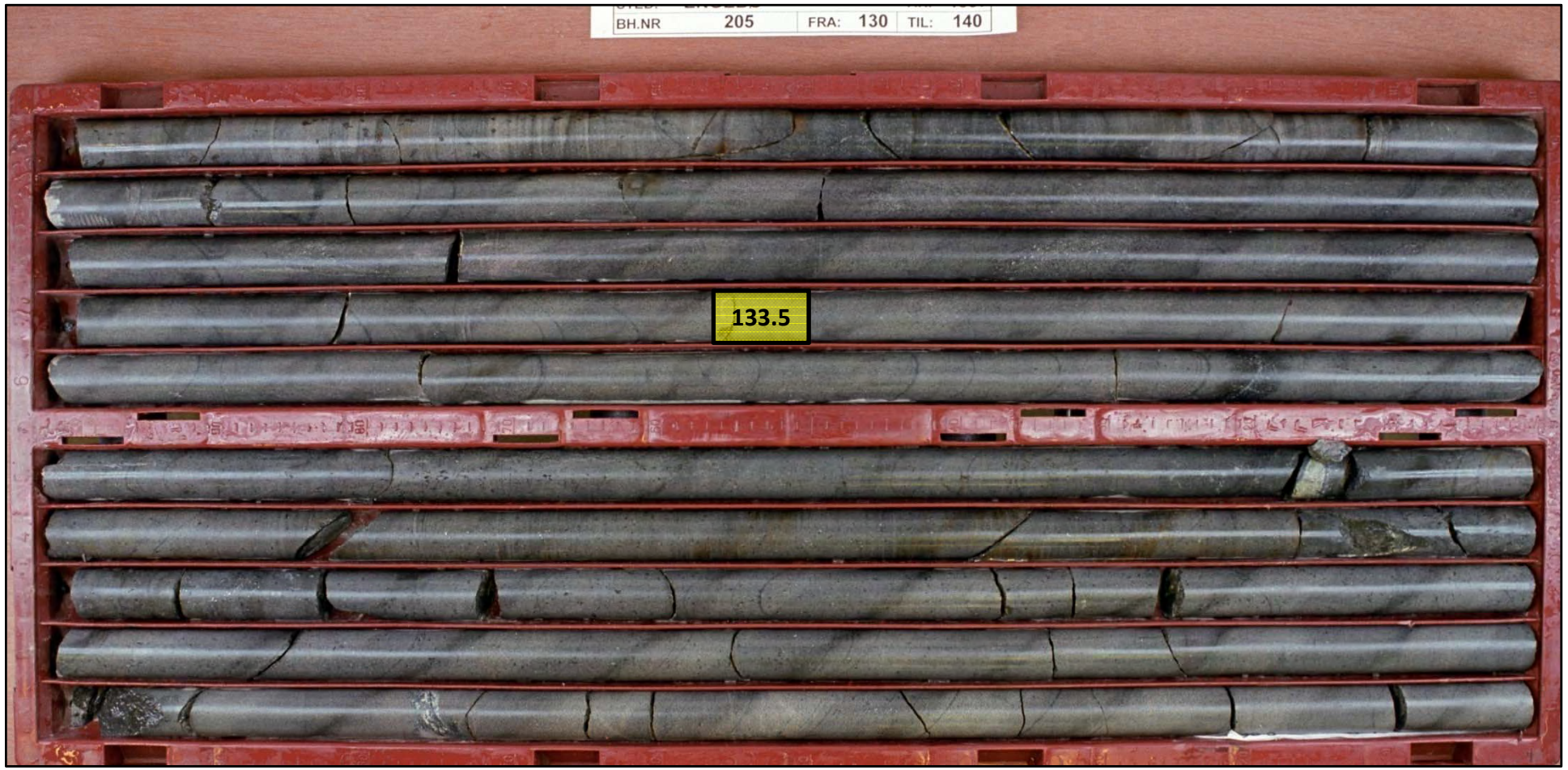
Engebøfjellet core sample information

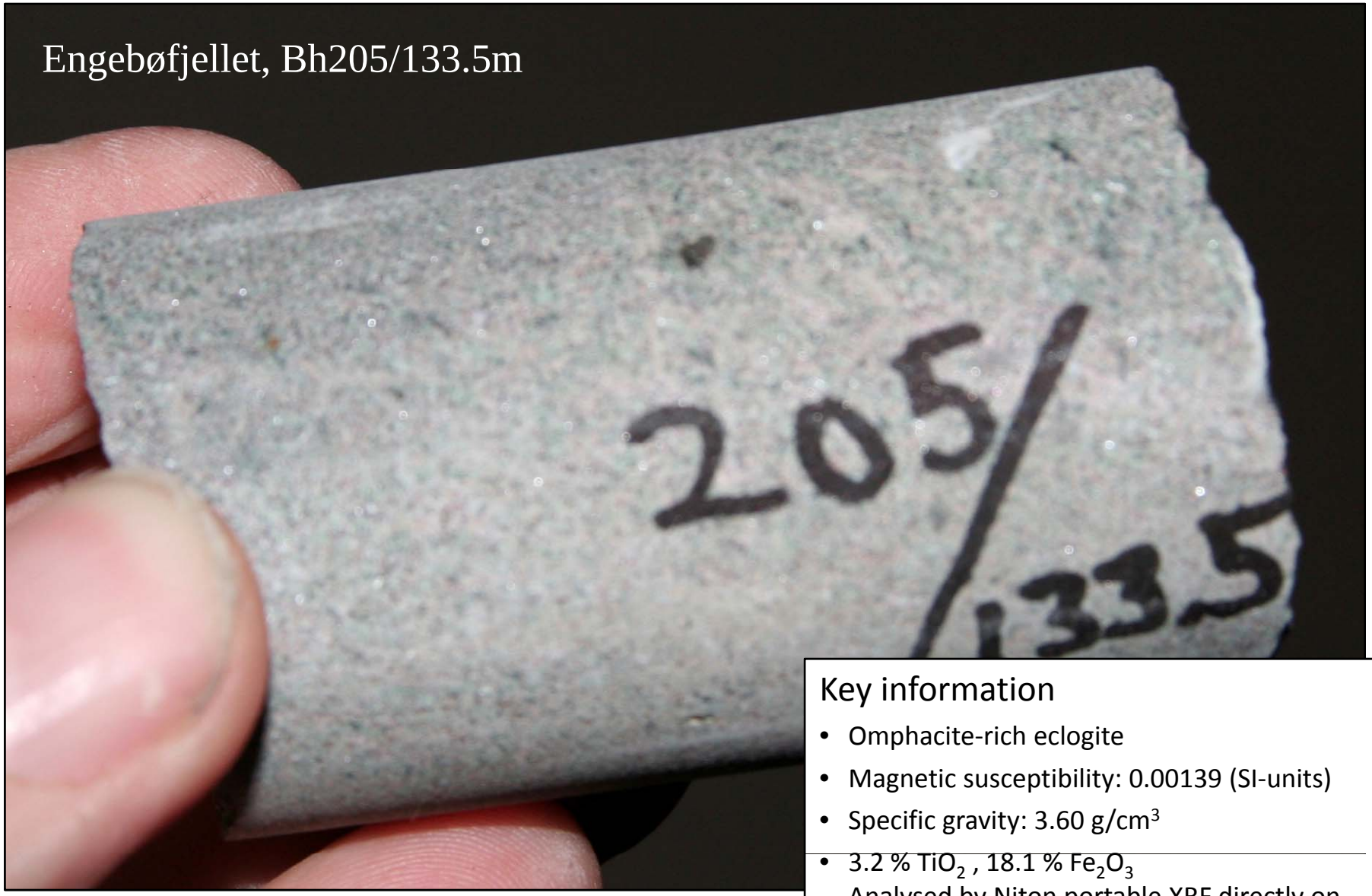
Sample Dh205/133.5m



Comments - 10 m core section

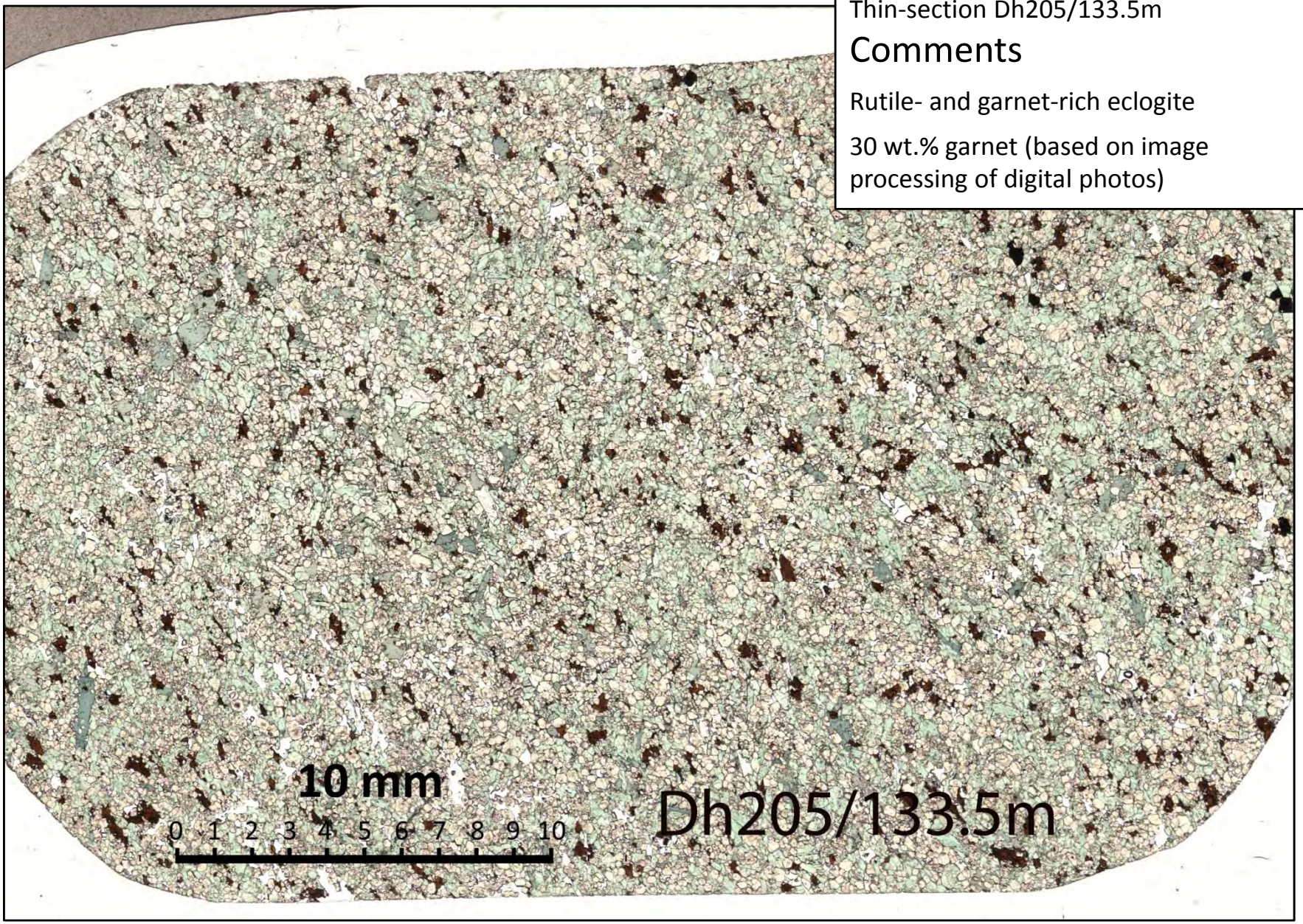
- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; some retrograde alteration along fractures affect a minor portion of the rock; sample 205/133.5 is representative for a large amounts of eclogite in this part of the deposit.





Key information

- Omphacite-rich eclogite
- Magnetic susceptibility: 0.00139 (SI-units)
- Specific gravity: 3.60 g/cm^3
- 3.2 % TiO_2 , 18.1 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)



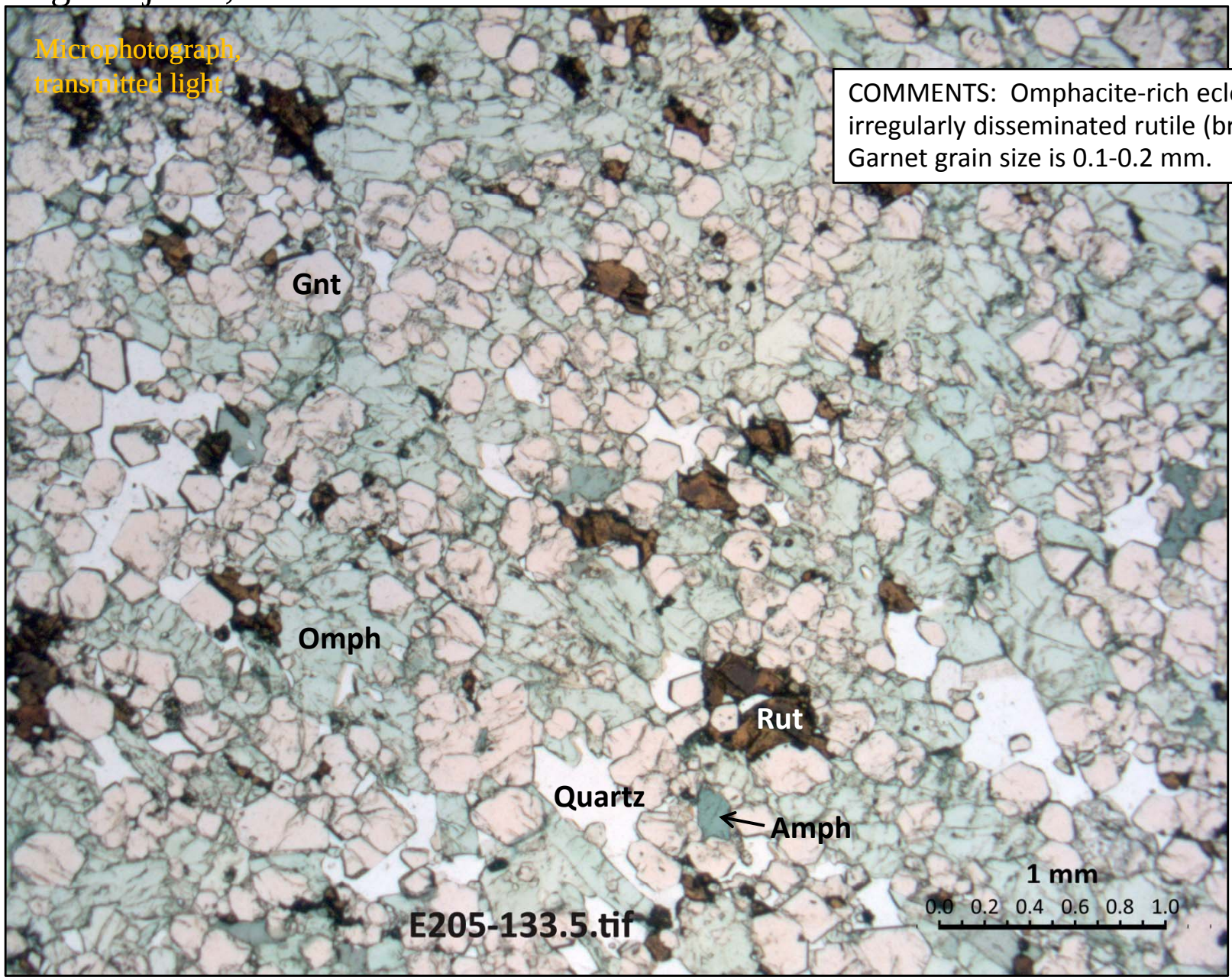
Thin-section Dh205/133.5m

Comments

Rutile- and garnet-rich eclogite

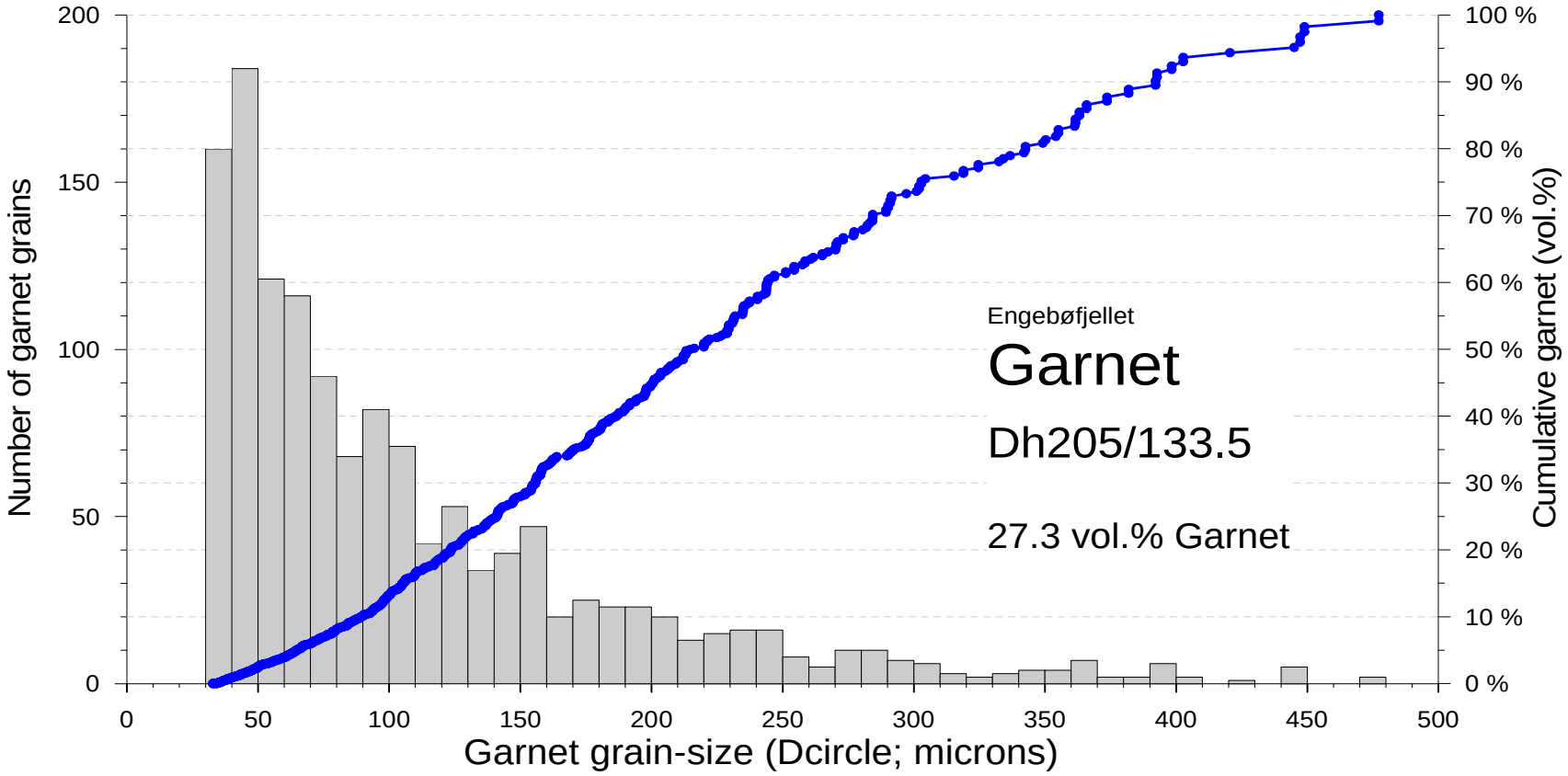
30 wt.% garnet (based on image processing of digital photos)

Engebøfjellet, Bh205/133.5m



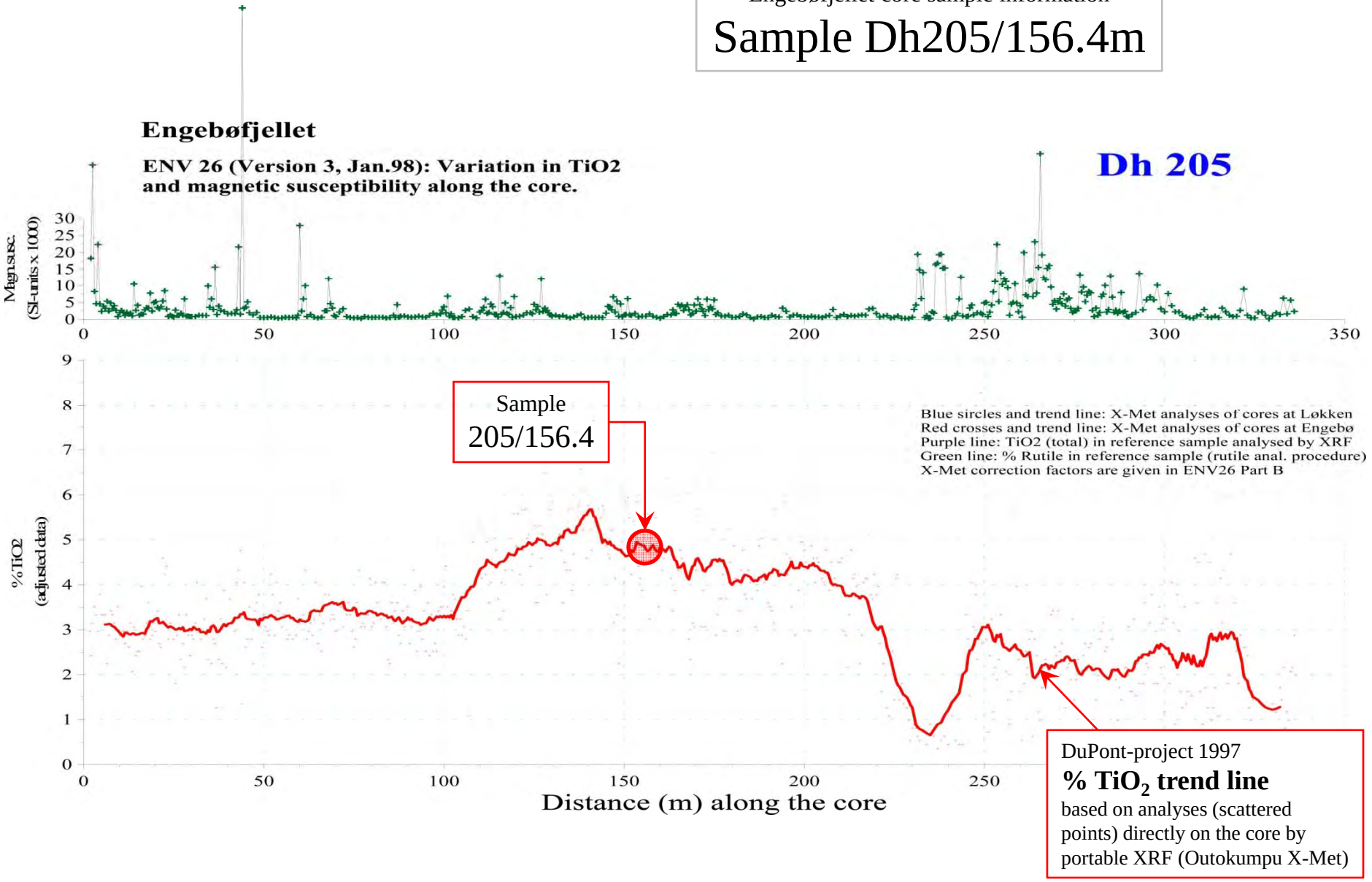
Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet is less than 220 microns. However, since grains attached to each other is registered as one larger grain by this method, the real 50 vol. % boundary is below 220 microns.



Engebøfjellet core sample information

Sample Dh205/156.4m



Comments - 10 m core section

- Digital photo scanned from 35 mm film (DuPont-project 1997).
- Garnet-rich eclogite; some retrograde alteration along fractures affecting a minor portion of the rock; sample 205/133.5 is representative for a large amounts of eclogite in this part of the deposit.

Engebøfjellet, Bh205/156.4m

Key information

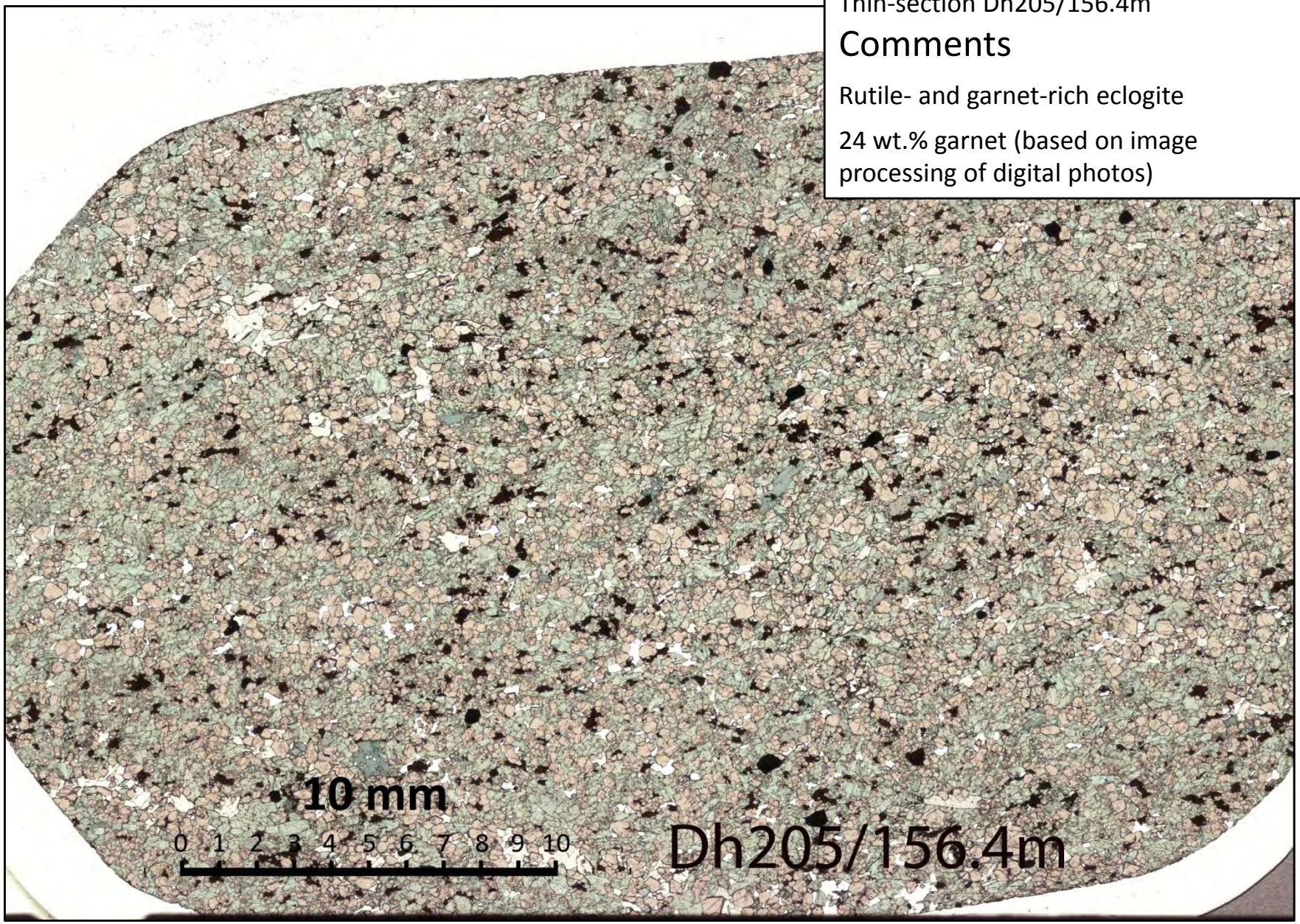
- Massive eclogite
- Magnetic susceptibility: 0.00200 (SI-units)
- Specific gravity: 3.60 g/cm^3
- 2.6 % TiO_2 , 17.4 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

Thin-section Dh205/156.4m

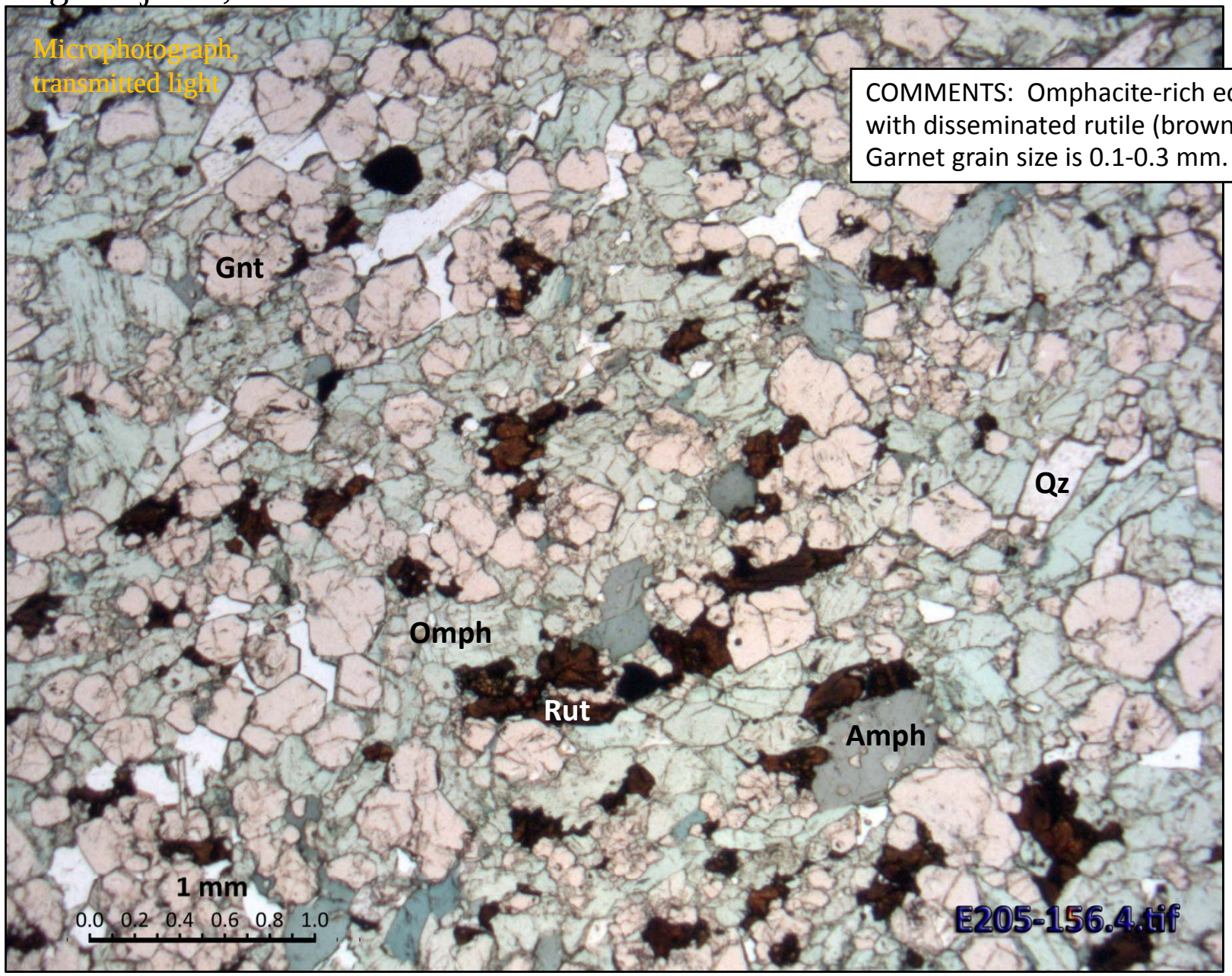
Comments

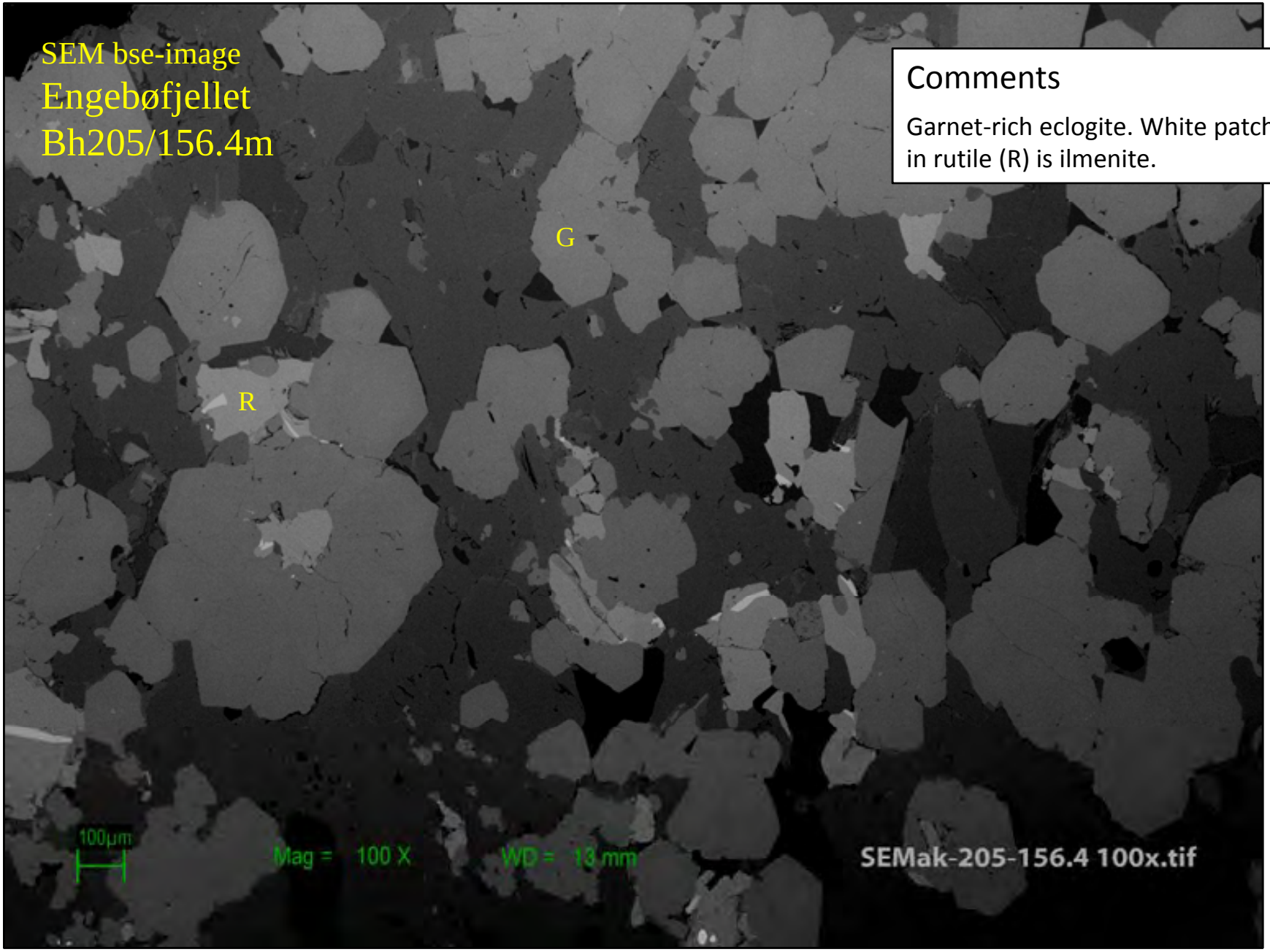
Rutile- and garnet-rich eclogite

24 wt.% garnet (based on image processing of digital photos)



Engebøfjellet, Bh205/156.4m



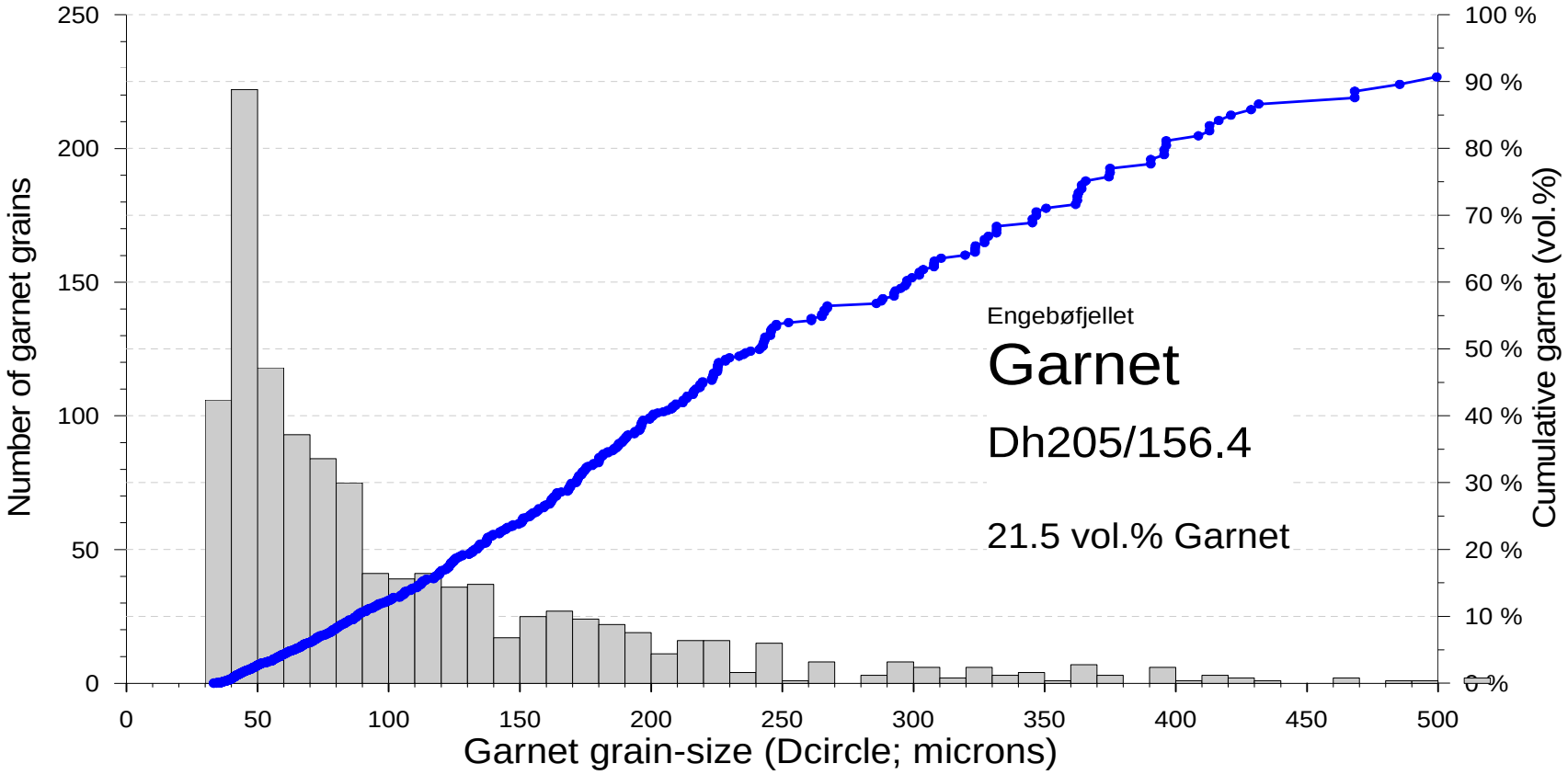


Comments

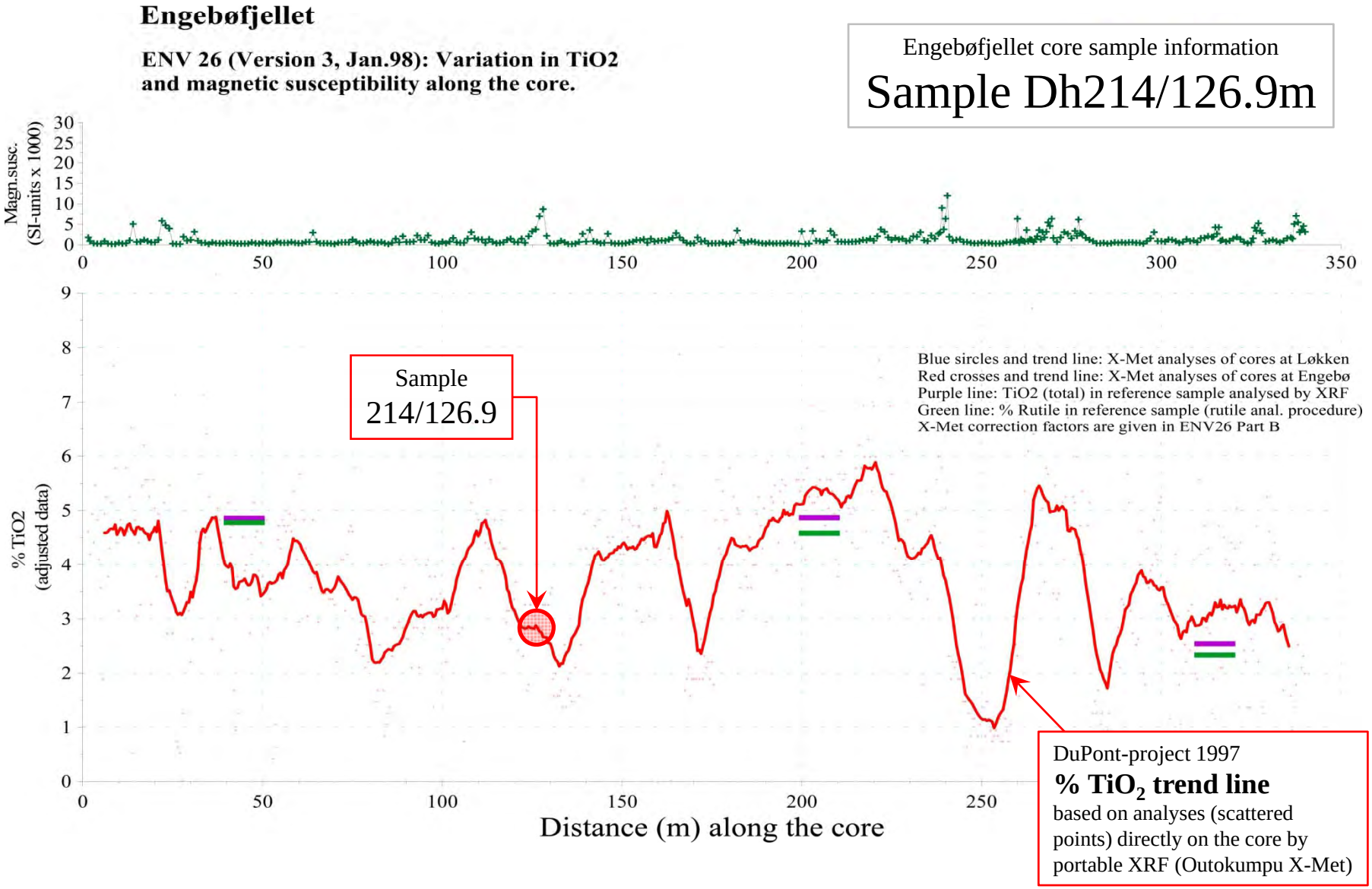
Garnet-rich eclogite. White patches in rutile (R) is ilmenite.

Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet is less than 240 microns. However, since grains attached to each other is registered as one larger grain by this method, the real 50 vol. % boundary is well below 240 microns.

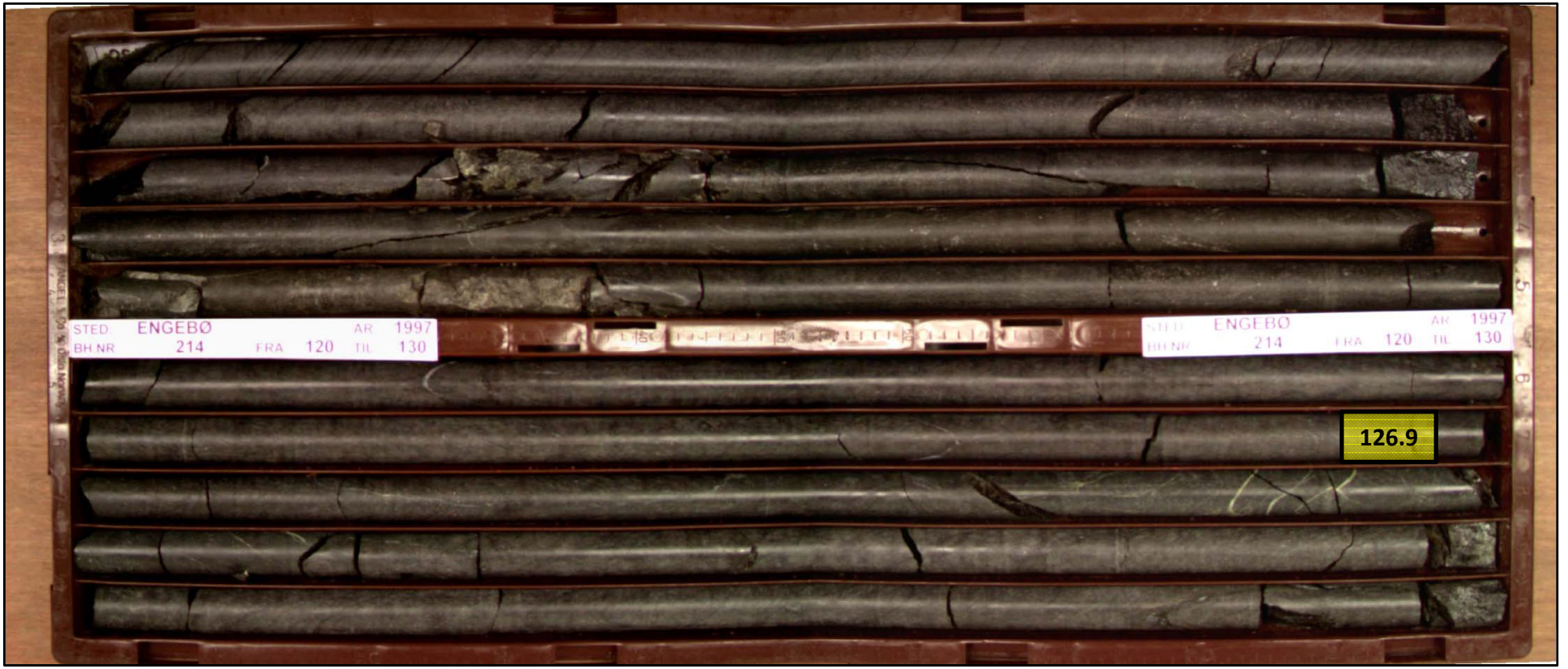


Dh214

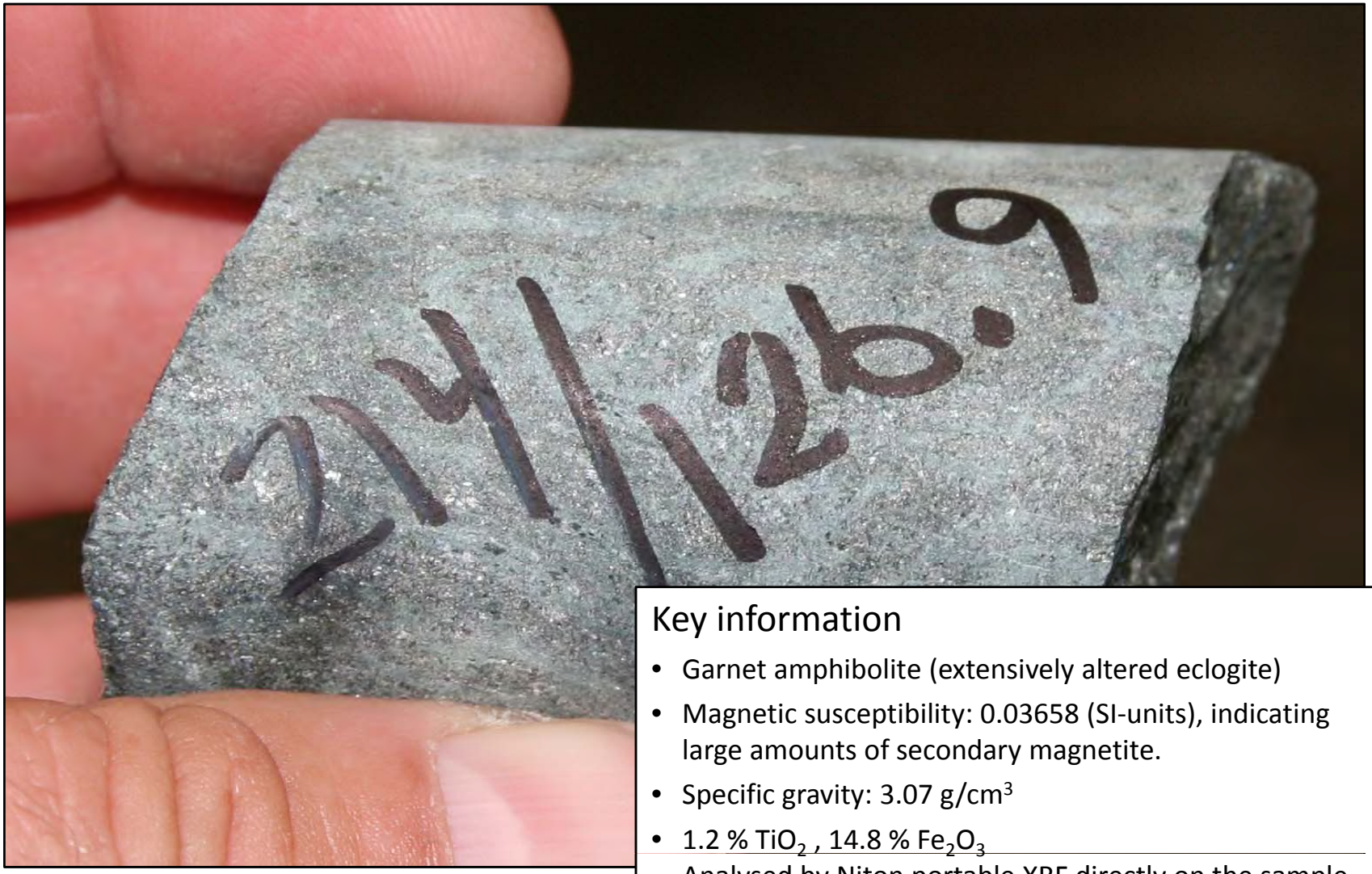

Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2 and magnetic susceptibility along the core.
Engebøfjellet core sample information
Sample Dh214/126.9m
Magn.susc. (SI-units x 1000)
% TiO2 (adjusted data)
Sample 214/126.9
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Distance (m) along the core
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo stitched from two low-quality digital photos (DuPont-project 1997).
- Amphibolitic eclogite due to pervasive retrograde alteration.



Engebøfjellet, Bh214/126.9m



Key information

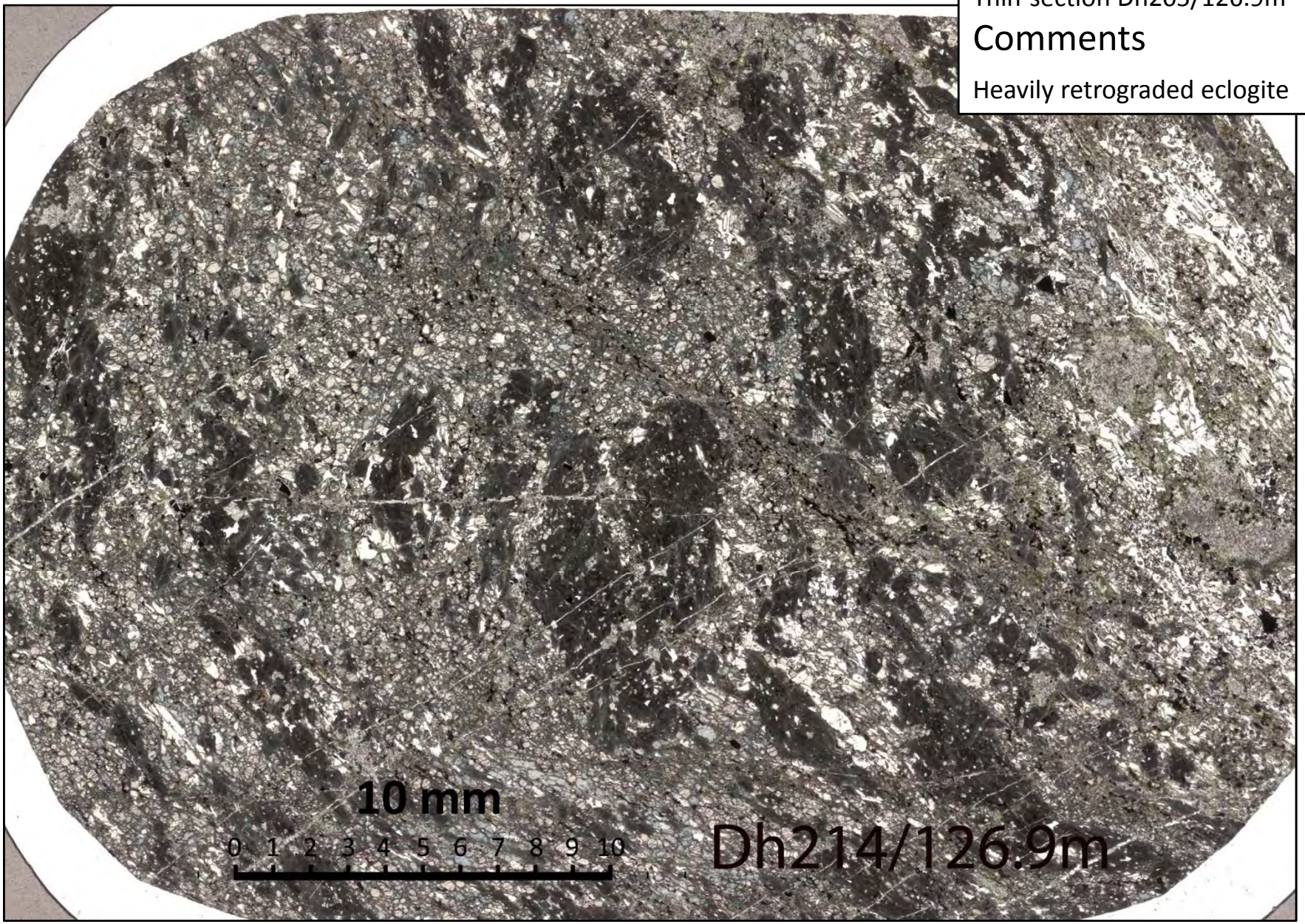
- Garnet amphibolite (extensively altered eclogite)
- Magnetic susceptibility: 0.03658 (SI-units), indicating large amounts of secondary magnetite.
- Specific gravity: 3.07 g/cm^3
- 1.2 % TiO_2 , 14.8 % Fe_2O_3

  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

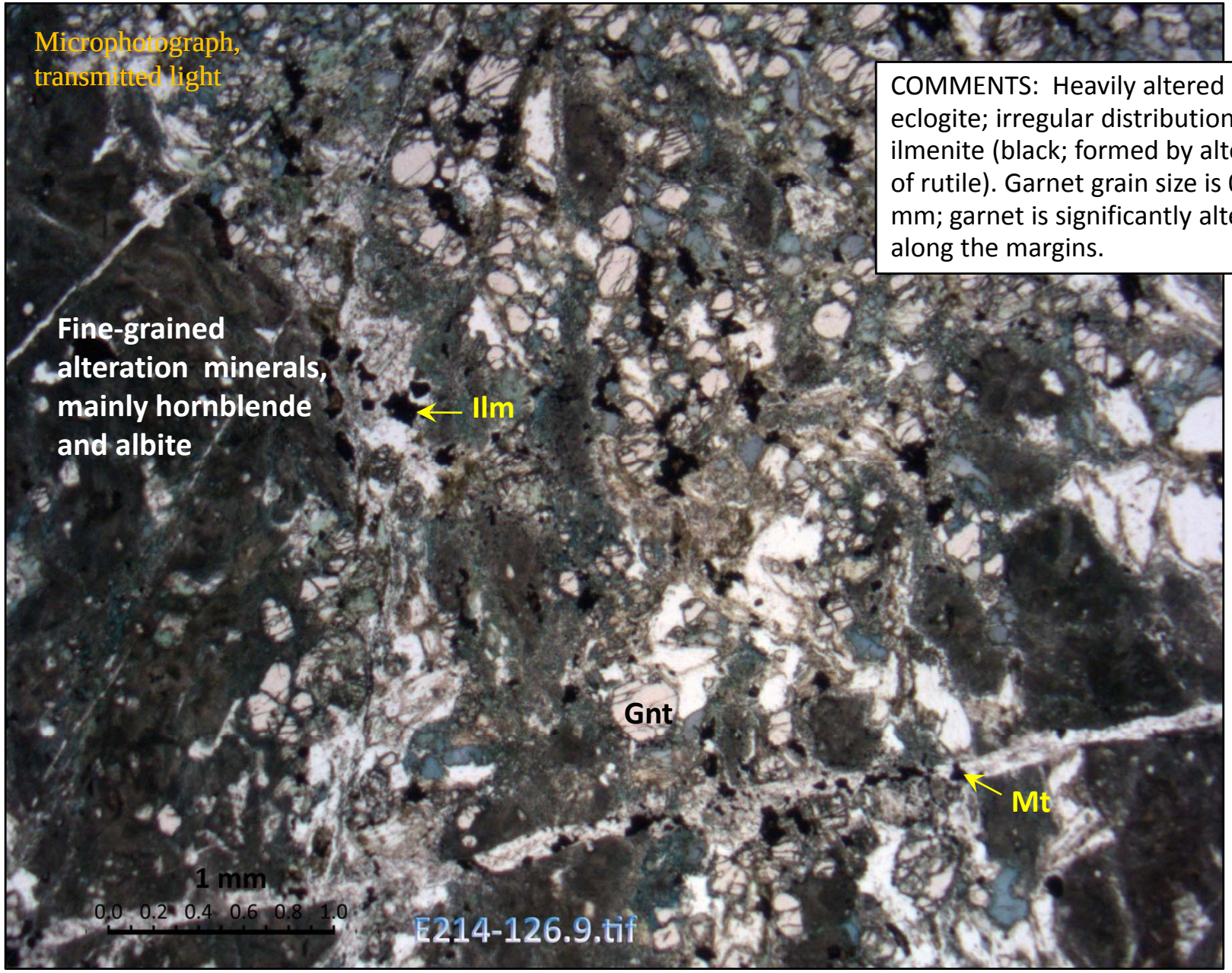
Thin-section Dh205/126.9m

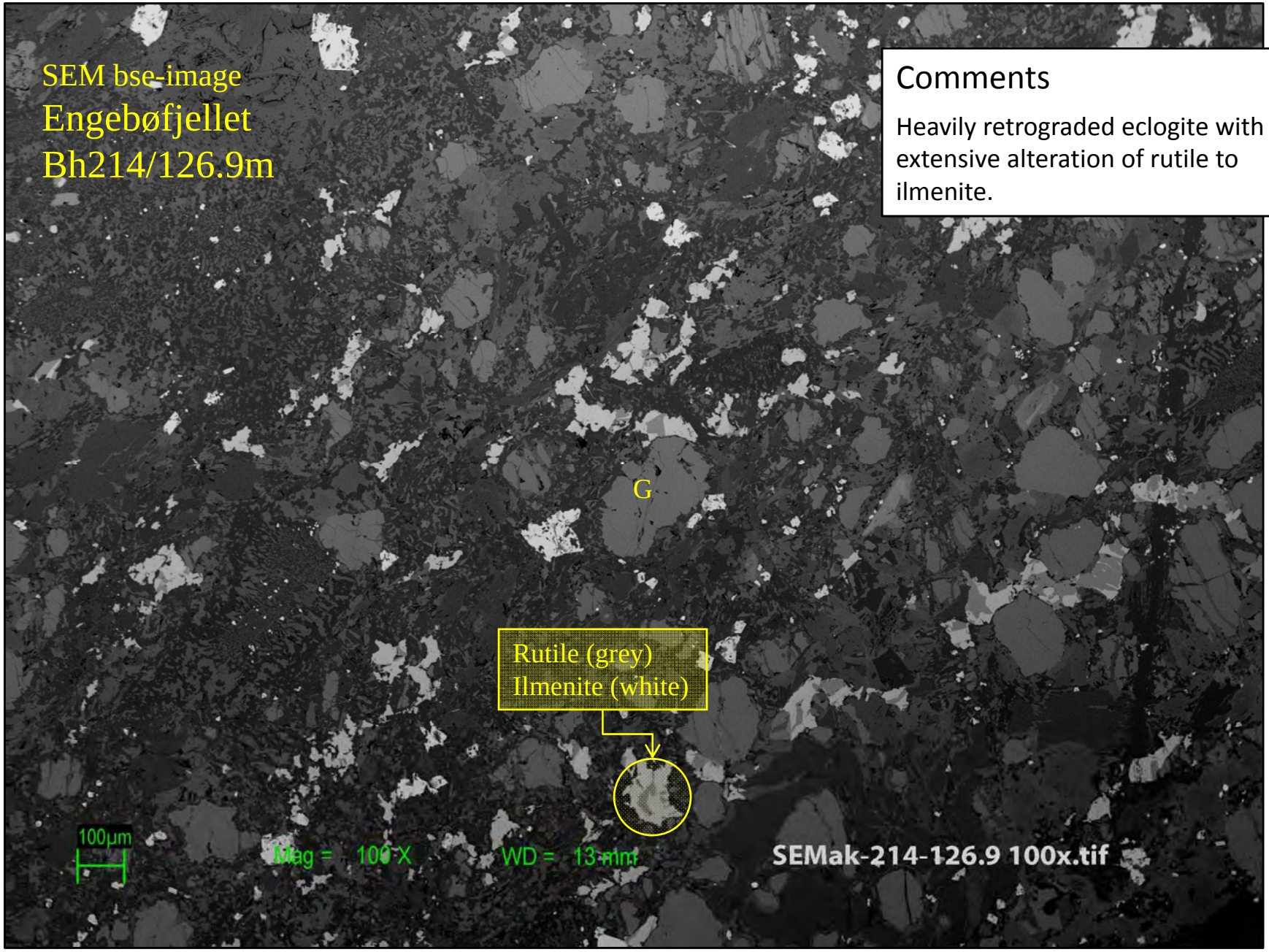
Comments

Heavily retrograded eclogite

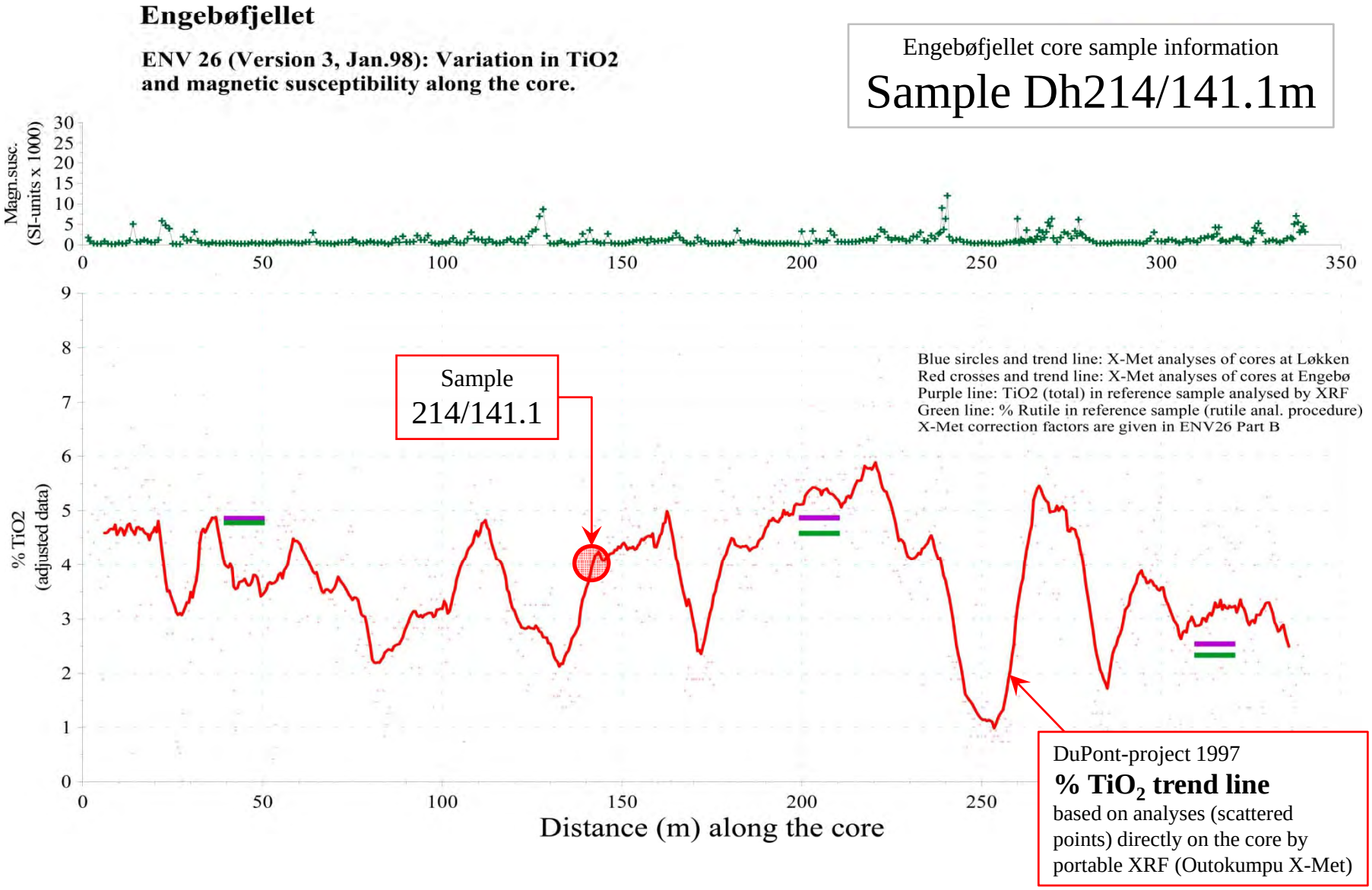


Engebøfjellet, Bh214/126.9m



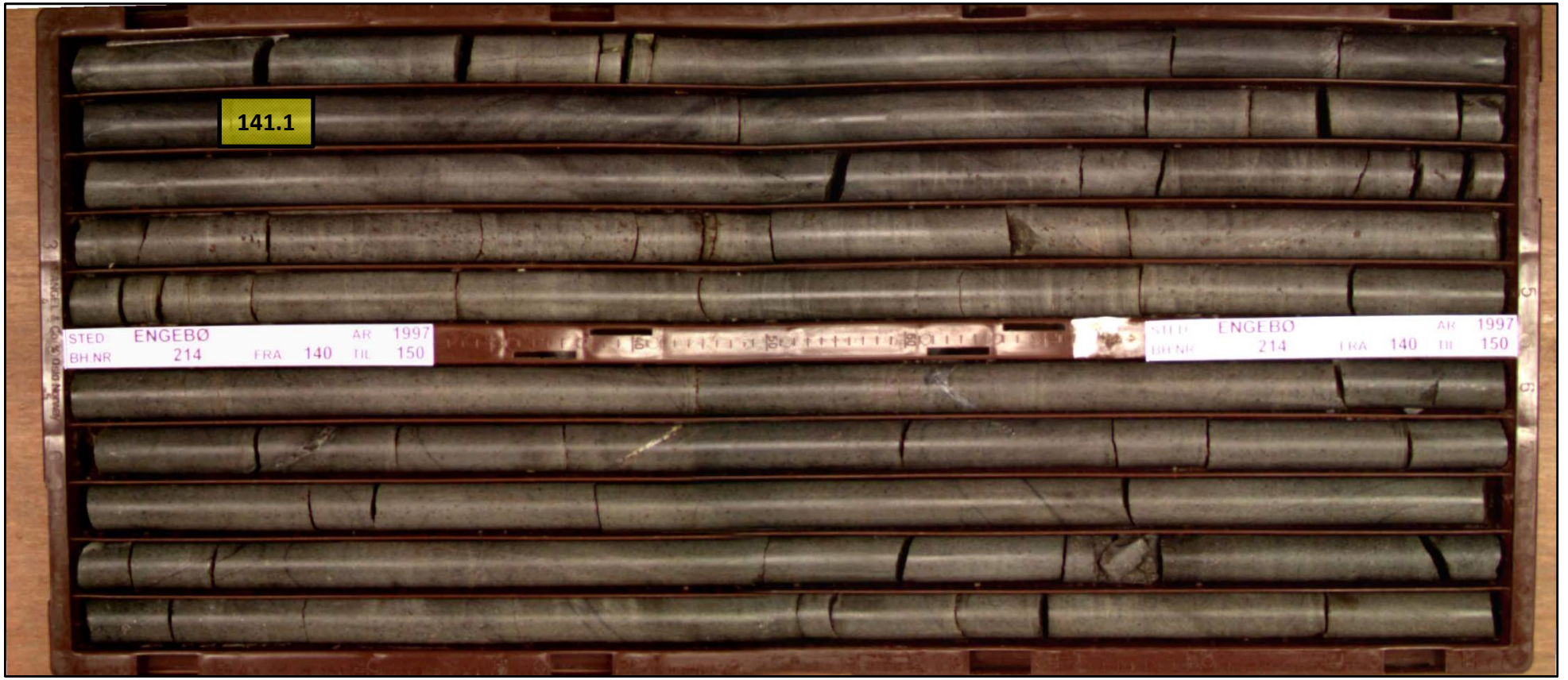

SEM bse-image
Engebøfjellet
Bh214/126.9m
Comments
Heavily retrograded eclogite with extensive alteration of rutile to ilmenite.
G
Rutile (grey)
Ilmenite (white)
100µm
Mag = 100 X
WD = 13 mm
SEMak-214-126.9 100x.tif

Dh214


Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2 and magnetic susceptibility along the core.
Engebøfjellet core sample information
Sample Dh214/141.1m
Magn.susc. (SI-units x 1000)
% TiO2 (adjusted data)
Sample 214/141.1
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Distance (m) along the core
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo stitched from two low-quality digital photos (DuPont-project 1997).
- Massive eclogite; sample 214/141.1 is probably fairly representative for the respective part of the deposit.



Engebøfjellet, Bh214/141.1m

Key information

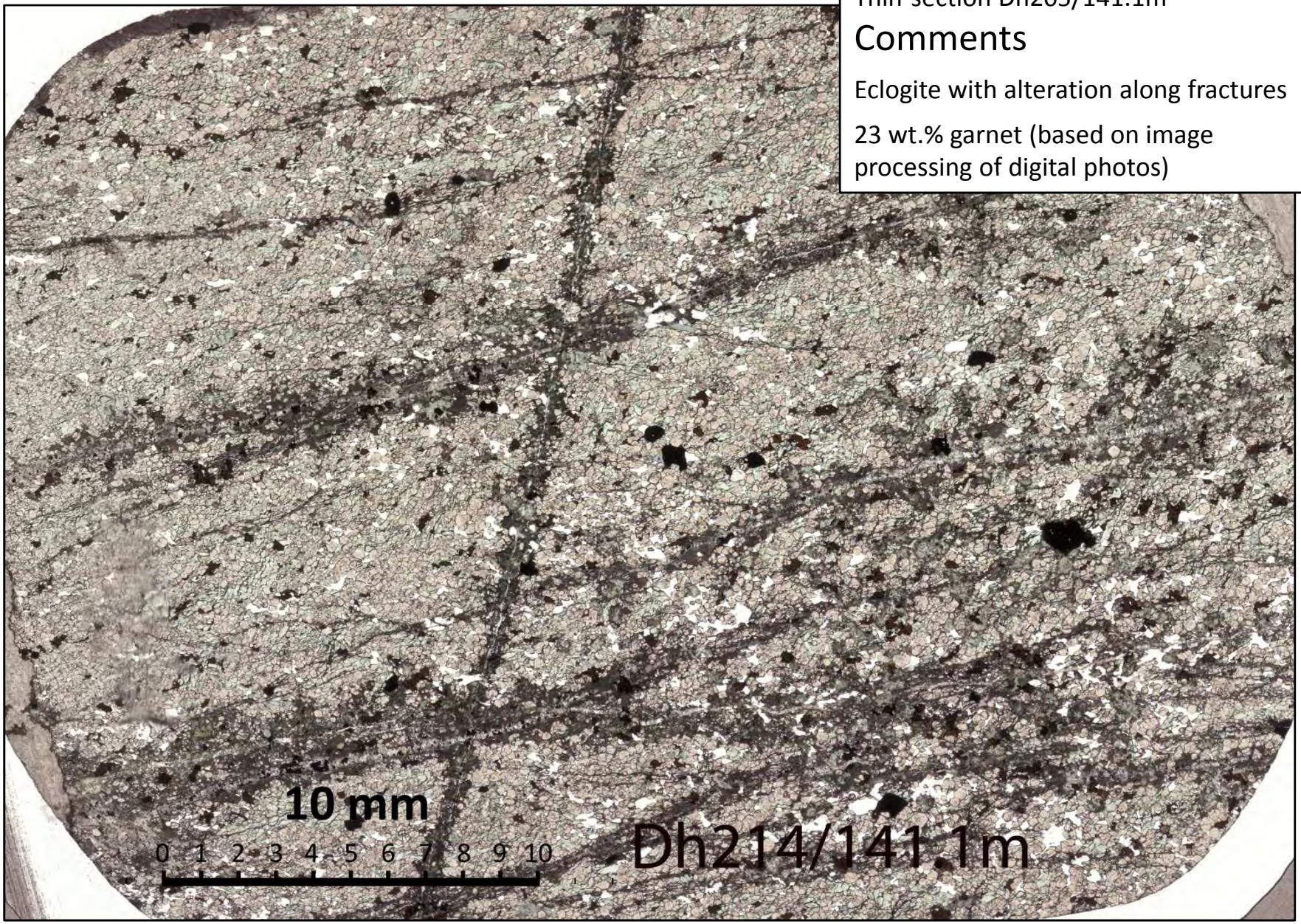
- Eclogite with alteration along fractures
- Magnetic susceptibility: 0.01367 (SI-units)
- Specific gravity: 3.48 g/cm^3
- 2.2 % TiO_2 , 17.0 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

Thin-section Dh205/141.1m

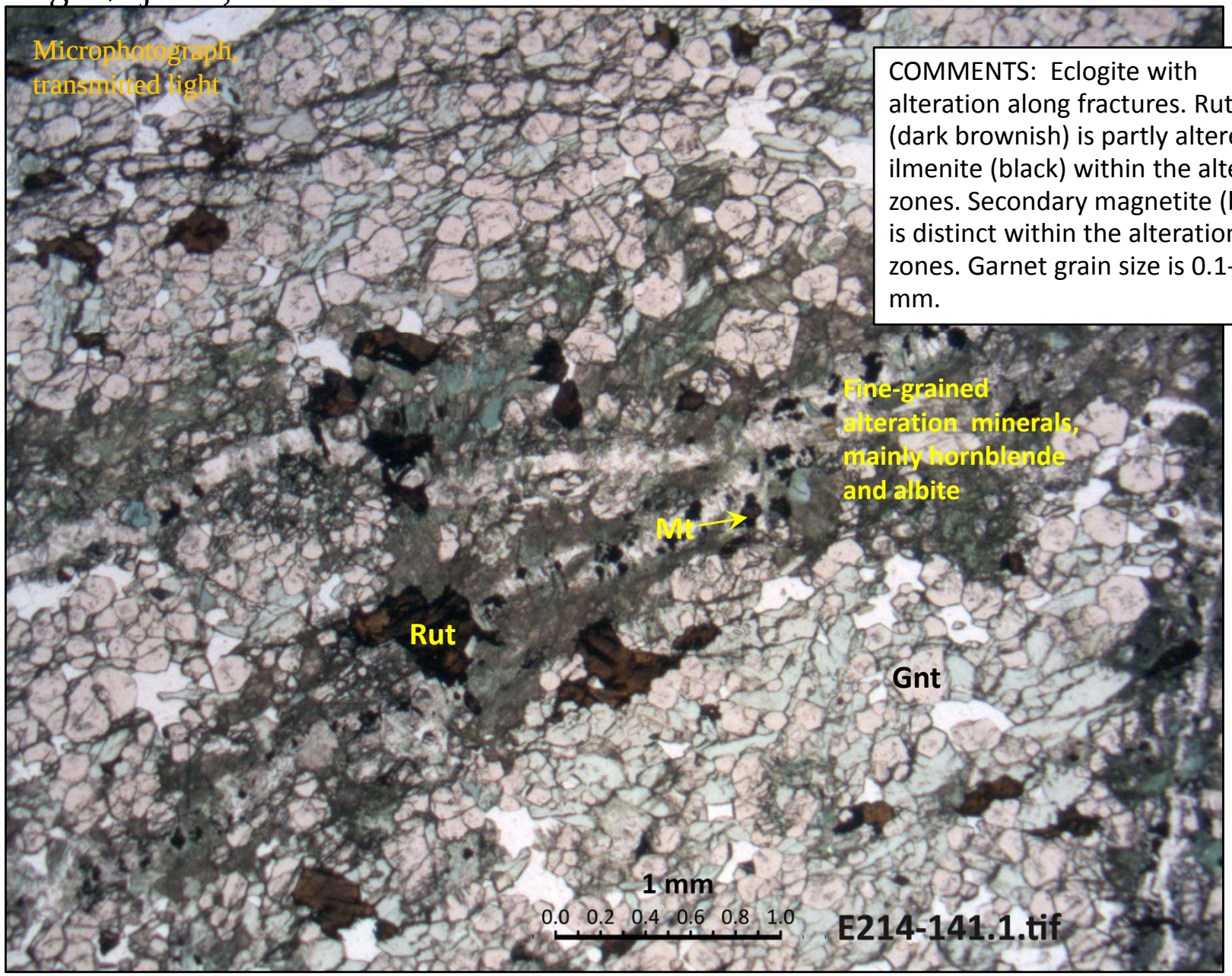
Comments

Eclogite with alteration along fractures

23 wt.% garnet (based on image processing of digital photos)

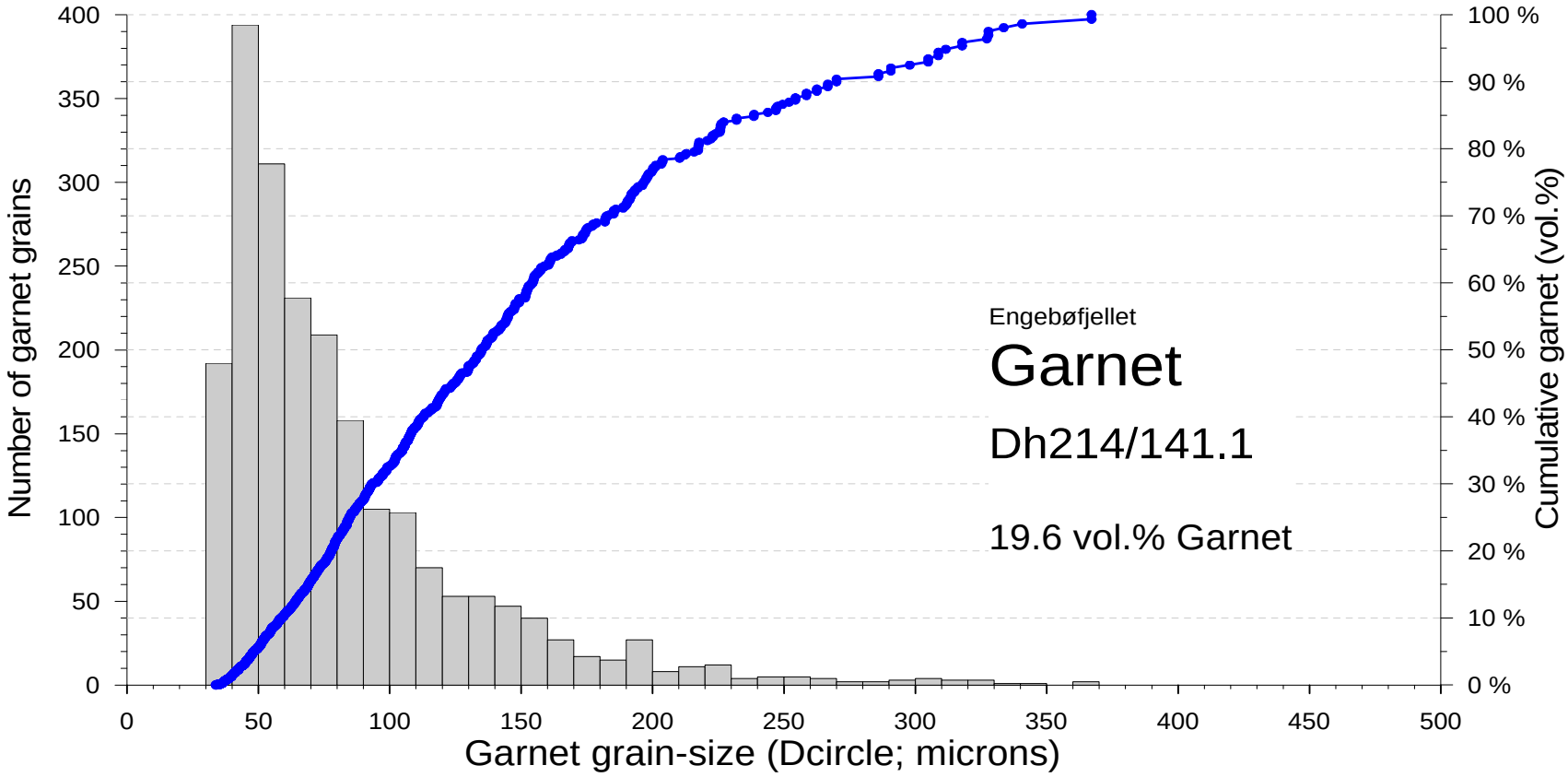


Engebøfjellet, Bh214/141.1m

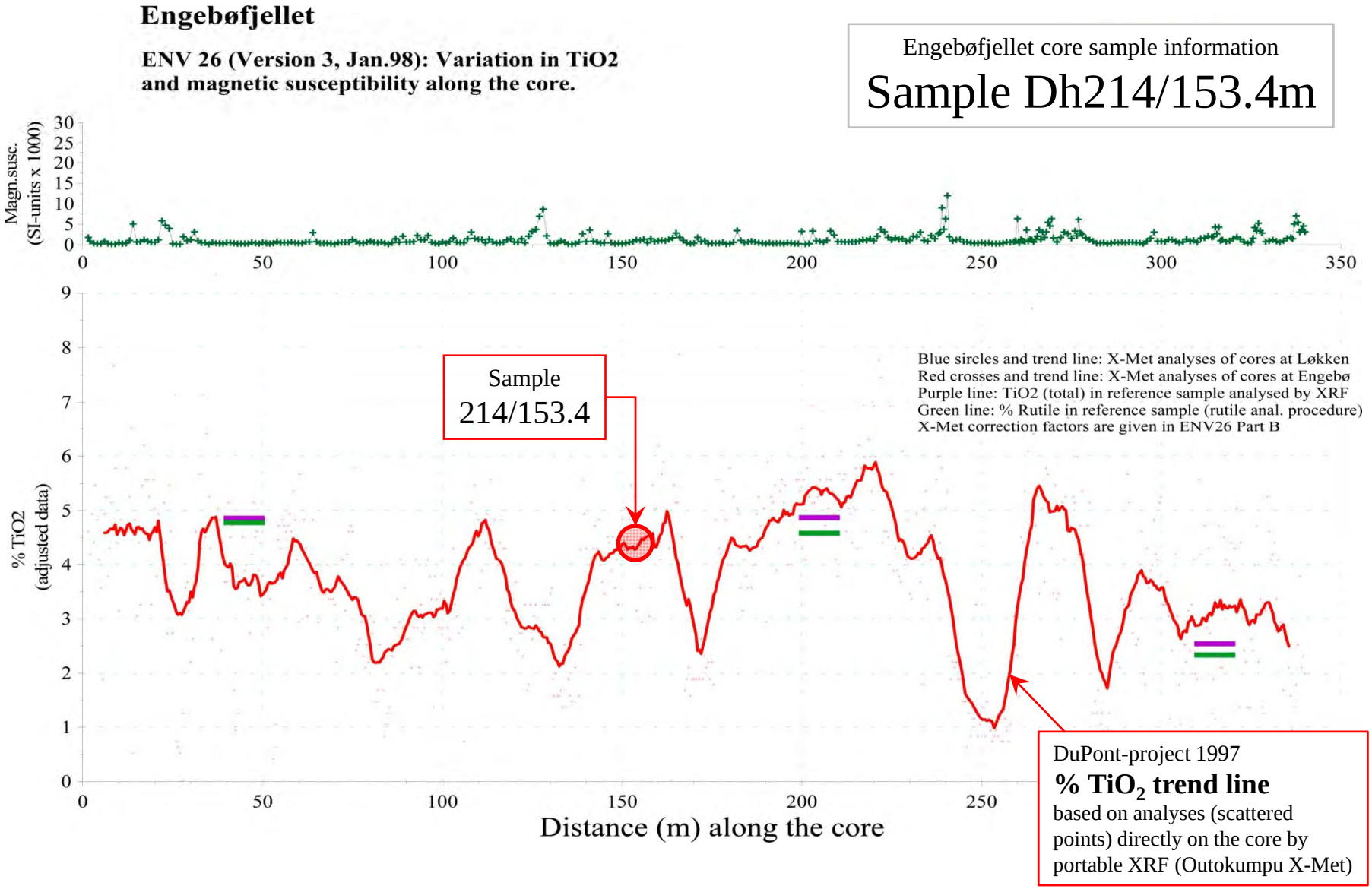


Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet is less than 140 microns. However, since grains attached to each other is registered as one larger grain by this method, the real 50 vol. % boundary is below 140 microns.

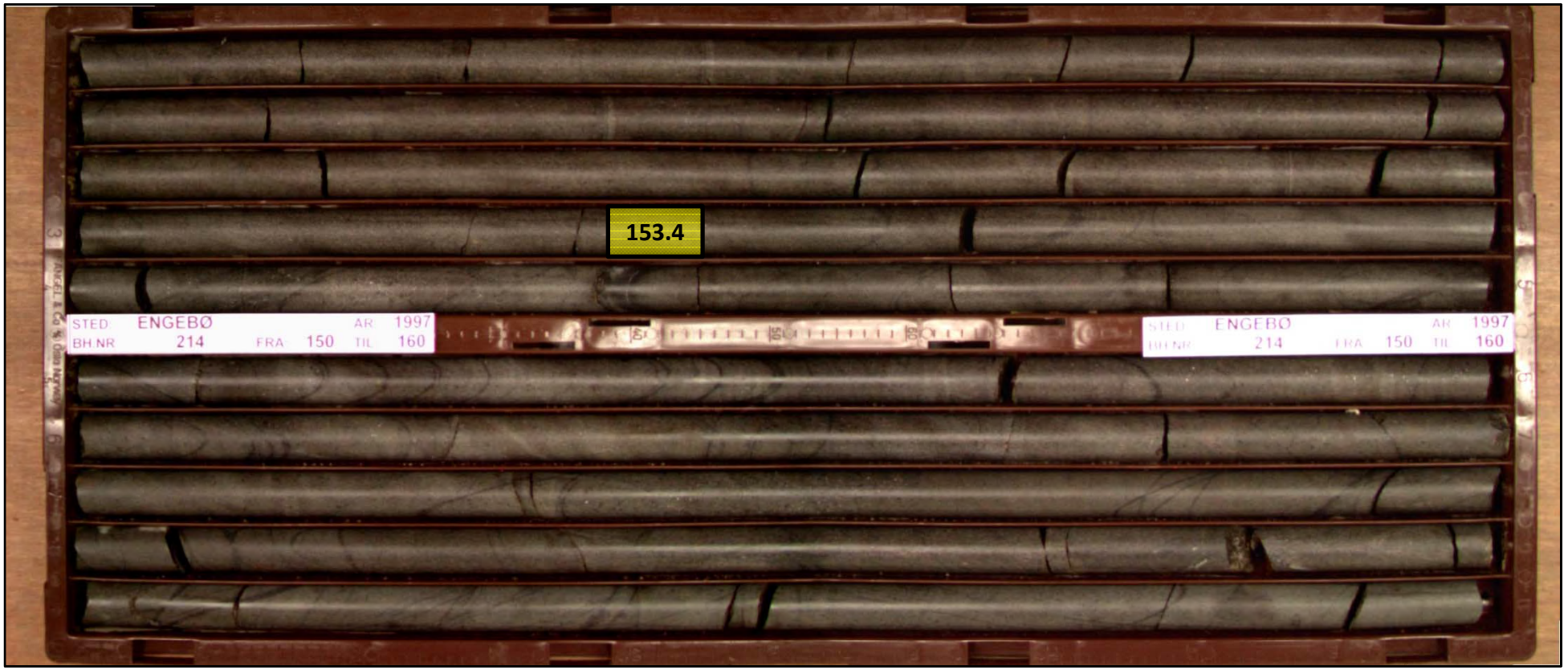


Dh214

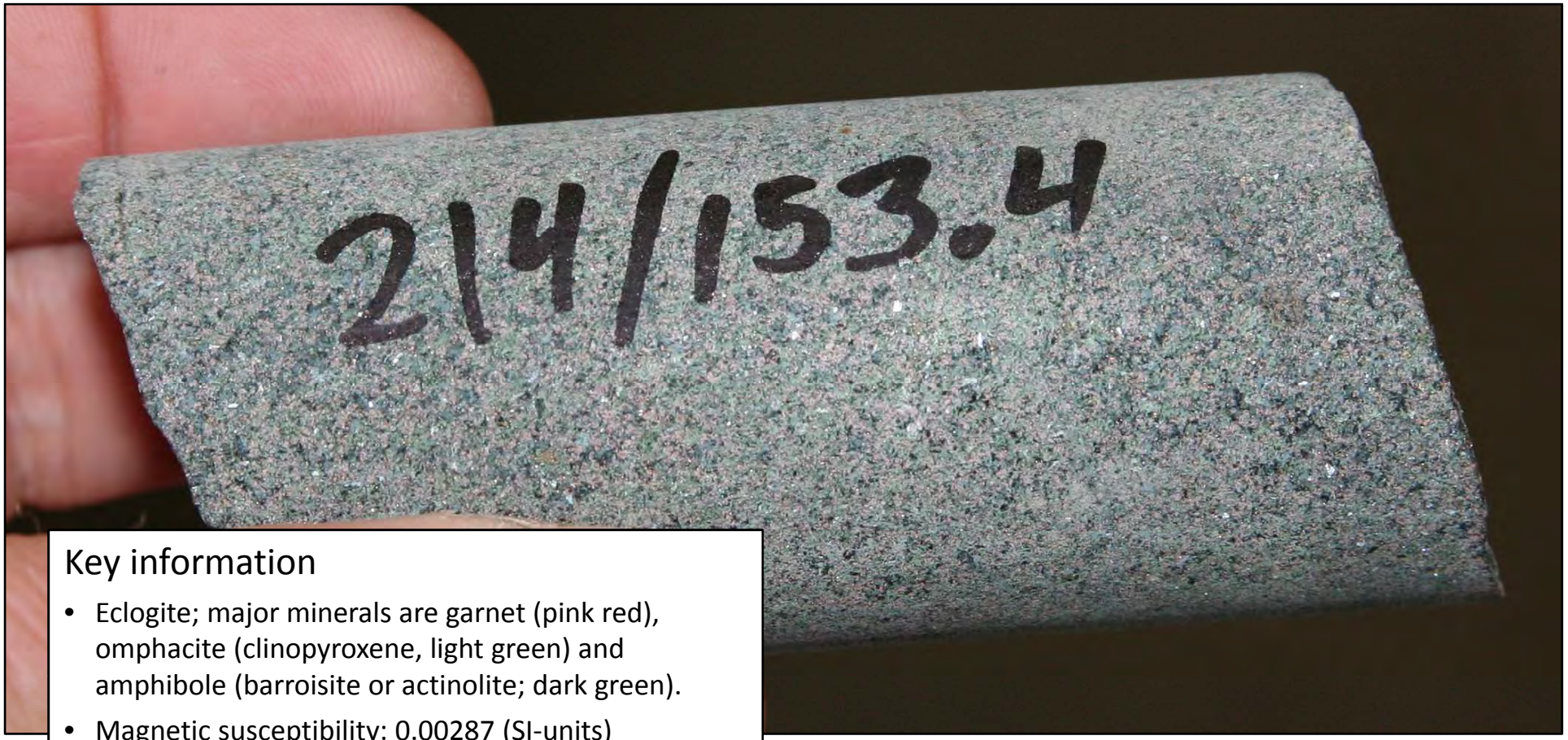

Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2 and magnetic susceptibility along the core.
Engebøfjellet core sample information
Sample Dh214/153.4m
Magn.susc. (SI-units x 1000)
% TiO2 (adjusted data)
Sample 214/153.4
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Distance (m) along the core
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo stitched from two low-quality digital photos (DuPont-project 1997).
- Massive eclogite; sample 214/153.4 is probably fairly representative .



Engebøfjellet, Bh214/153.4m



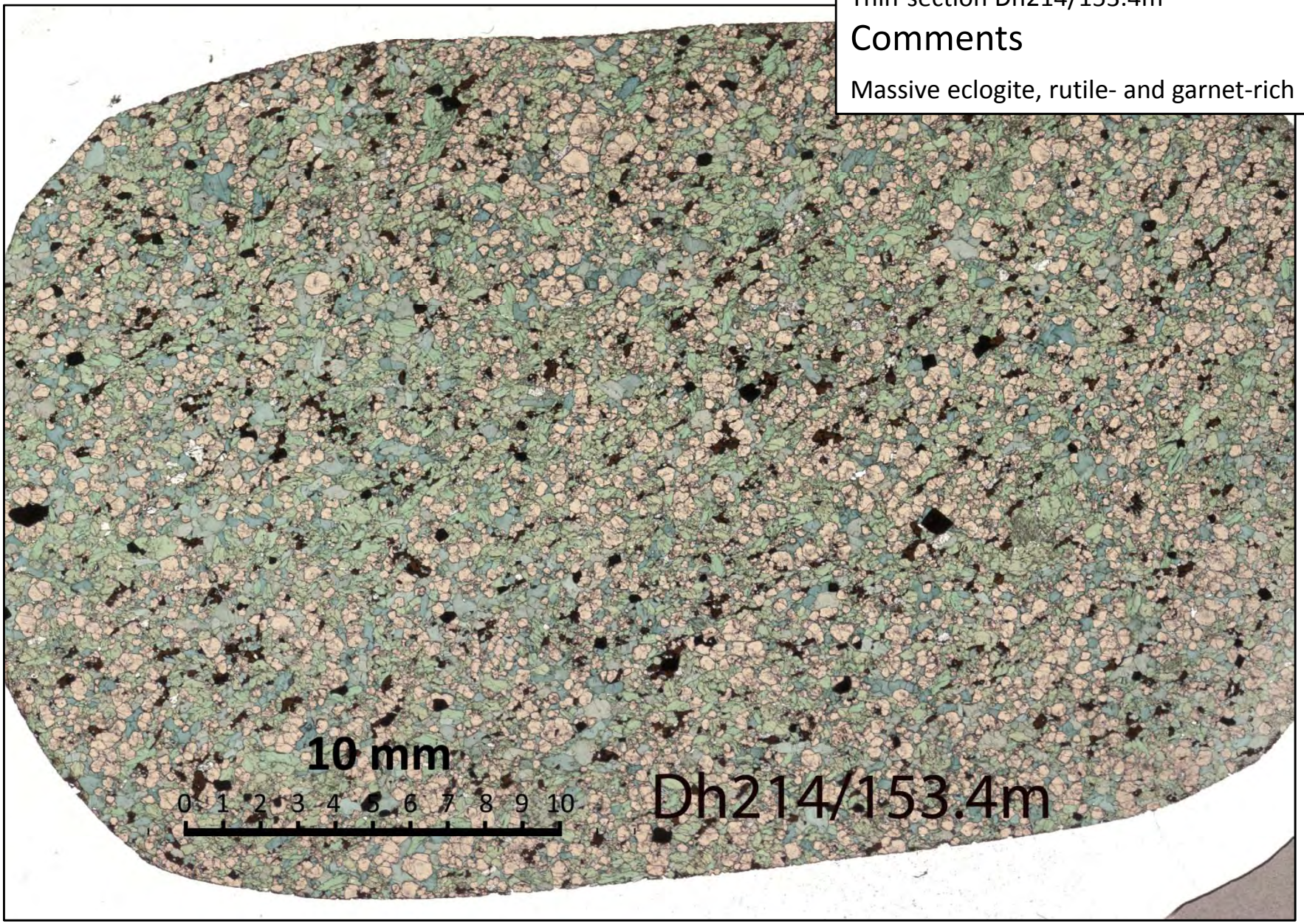
Key information

- Eclogite; major minerals are garnet (pink red), omphacite (clinopyroxene, light green) and amphibole (barroisite or actinolite; dark green).
- Magnetic susceptibility: 0.00287 (SI-units)
- Specific gravity: 3.57 g/cm^3
- 2.4 % TiO_2 , 20.4 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

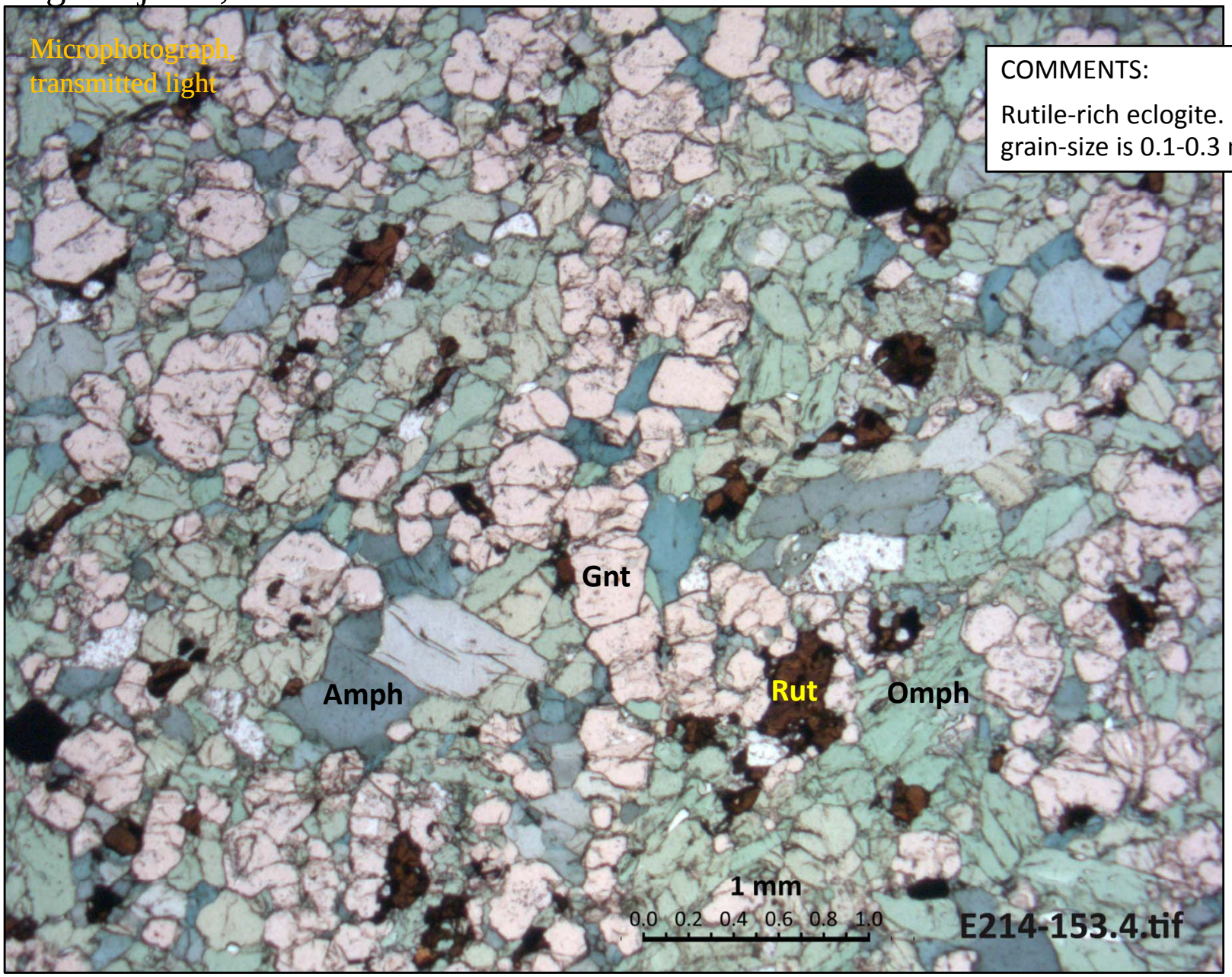
Thin-section Dh214/153.4m

Comments

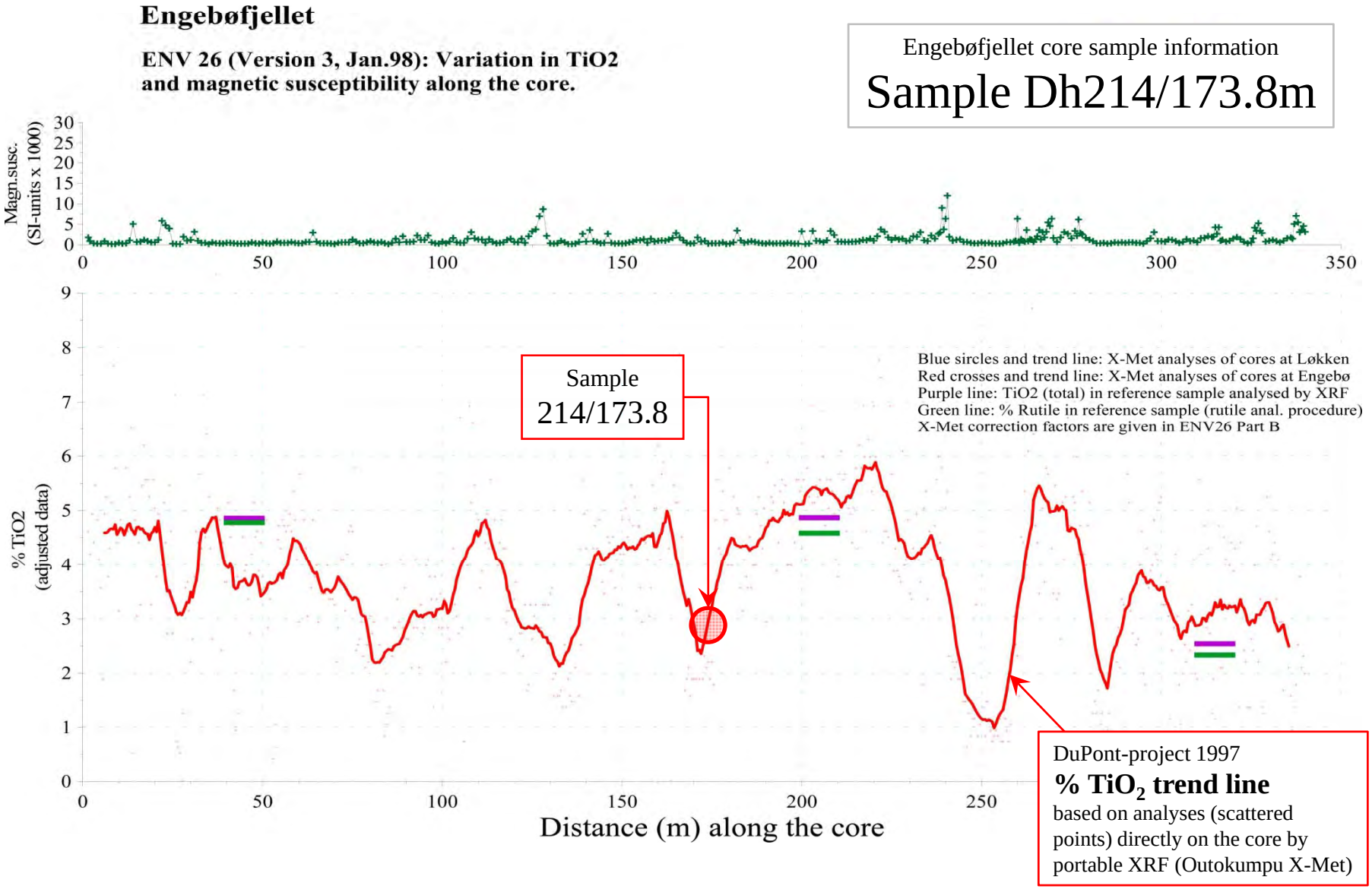
Massive eclogite, rutile- and garnet-rich



Engebøfjellet, Bh214/153.4m

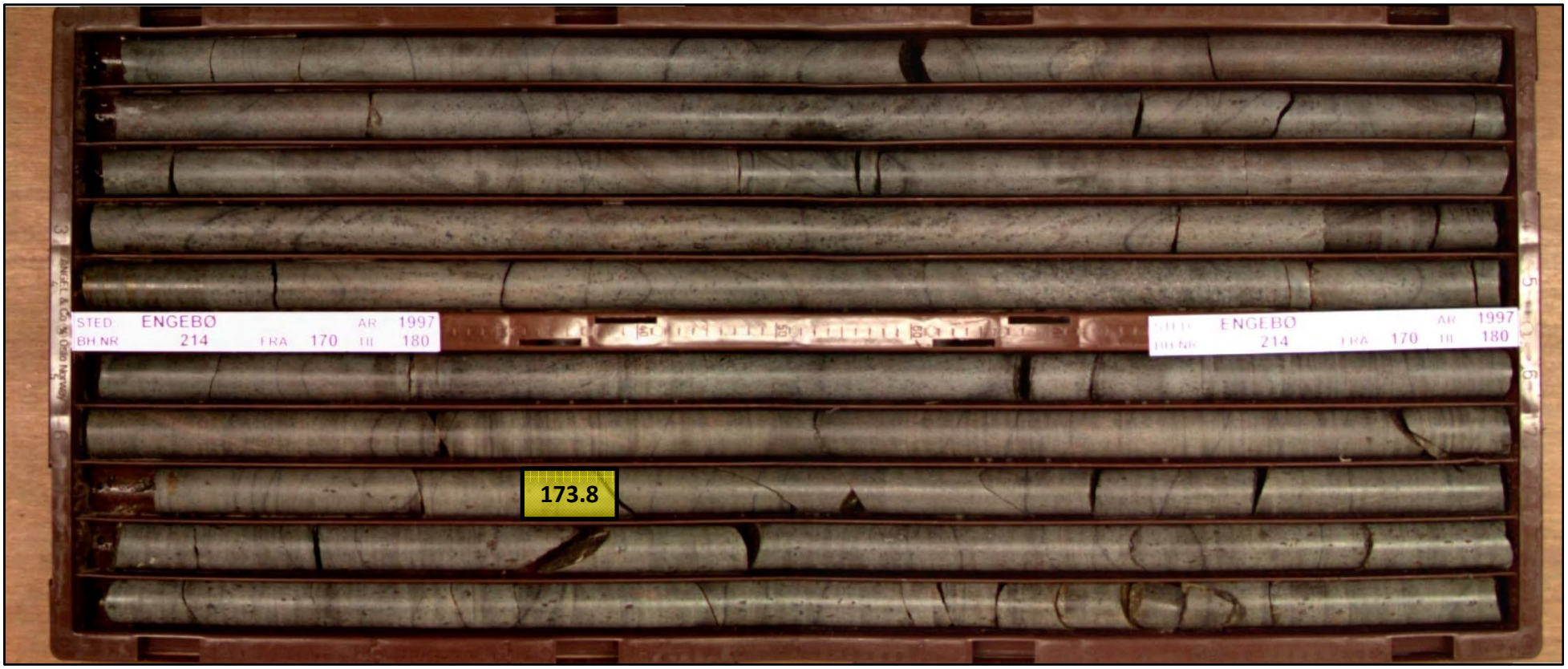


Dh214

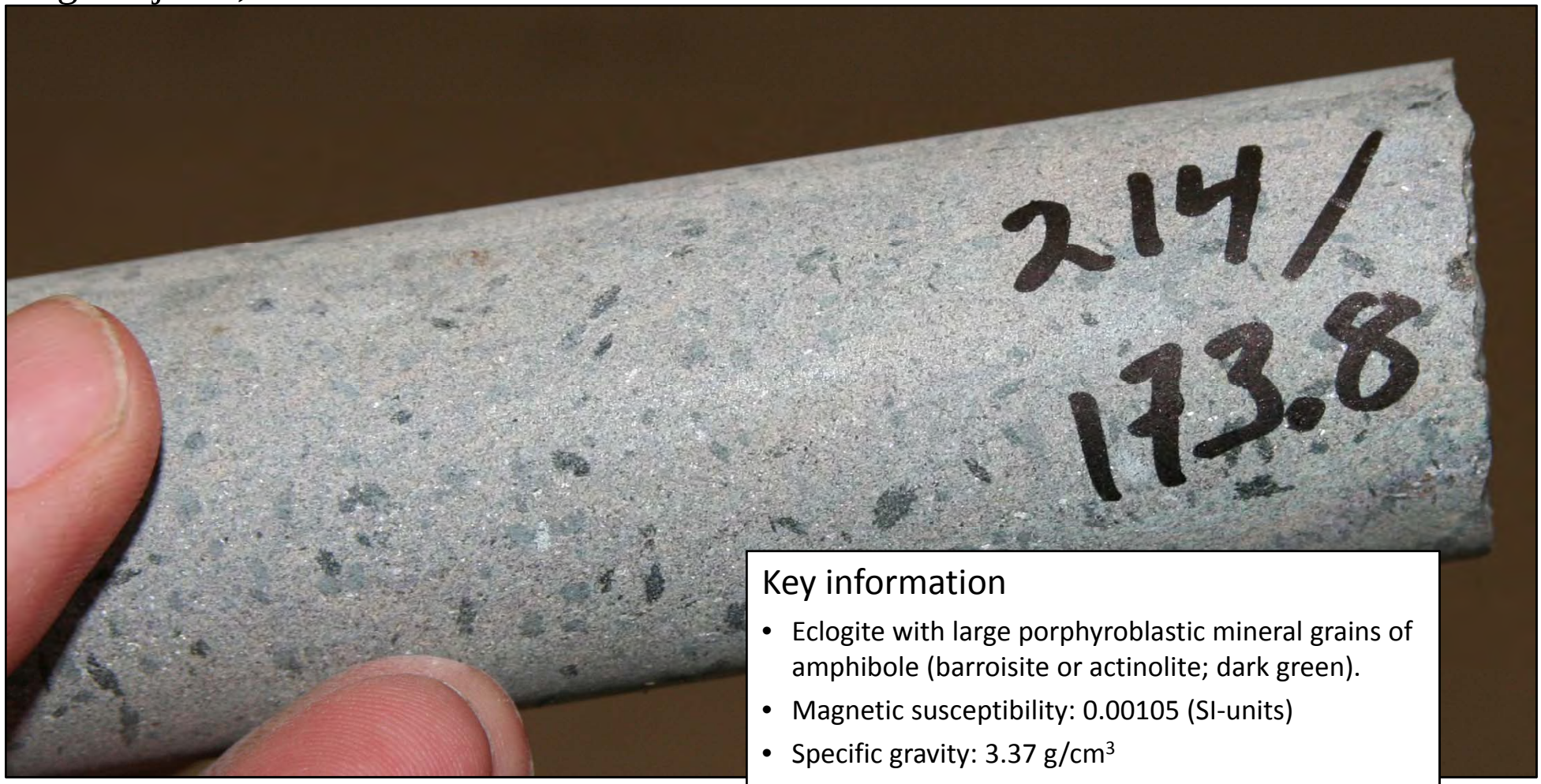

Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2 and magnetic susceptibility along the core.
Engebøfjellet core sample information
Sample Dh214/173.8m
Magn.susc. (SI-units x 1000)
% TiO2 (adjusted data)
Sample 214/173.8
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Distance (m) along the core
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo stitched from two low-quality digital photos (DuPont-project 1997).
- Massive eclogite with amphibole porphyroblasts.



Engebøfjellet, Bh214/173.8m



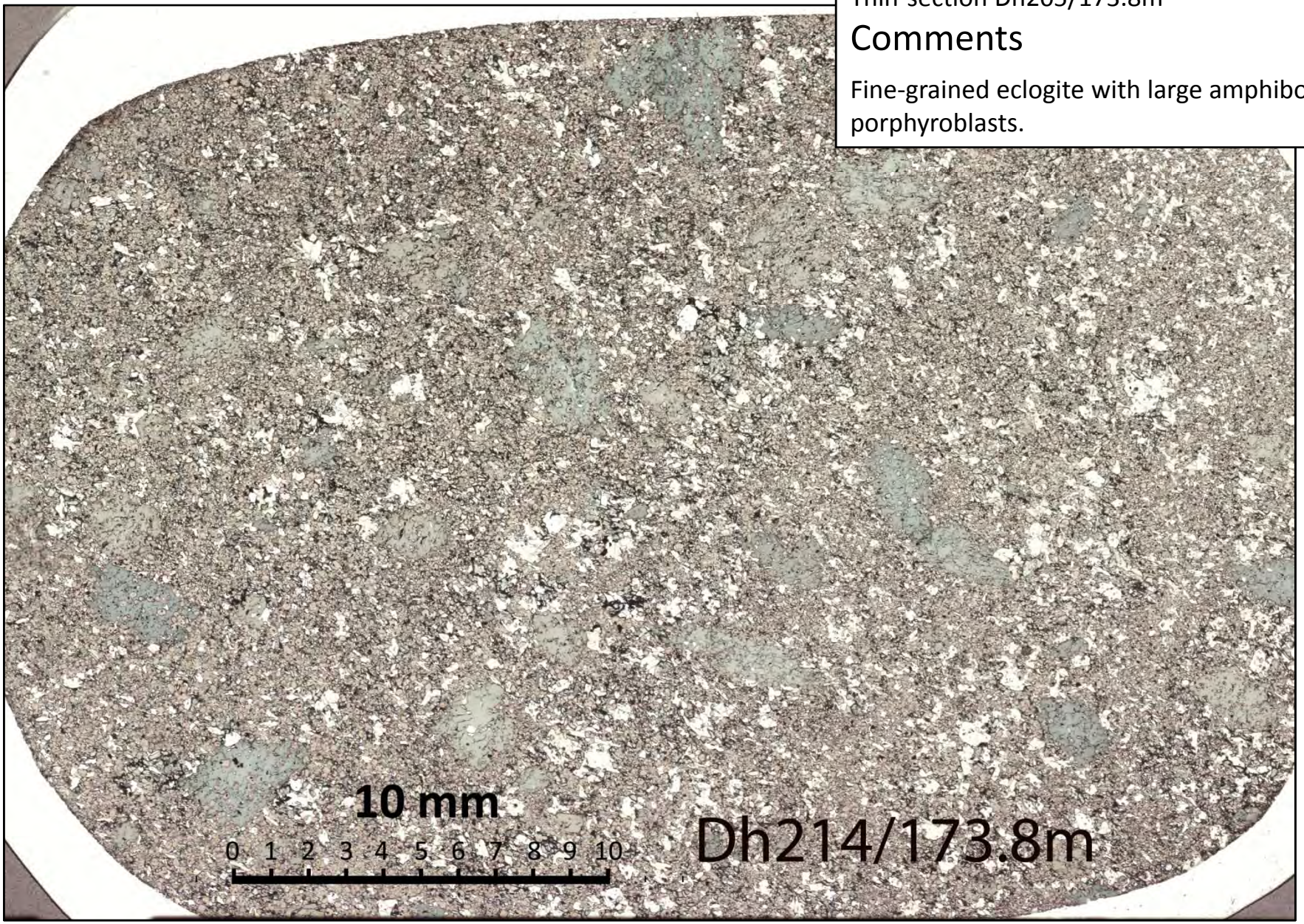
Key information

- Eclogite with large porphyroblastic mineral grains of amphibole (barroisite or actinolite; dark green).
- Magnetic susceptibility: 0.00105 (SI-units)
- Specific gravity: 3.37 g/cm^3
- 0.7 % TiO_2 , 12.8 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

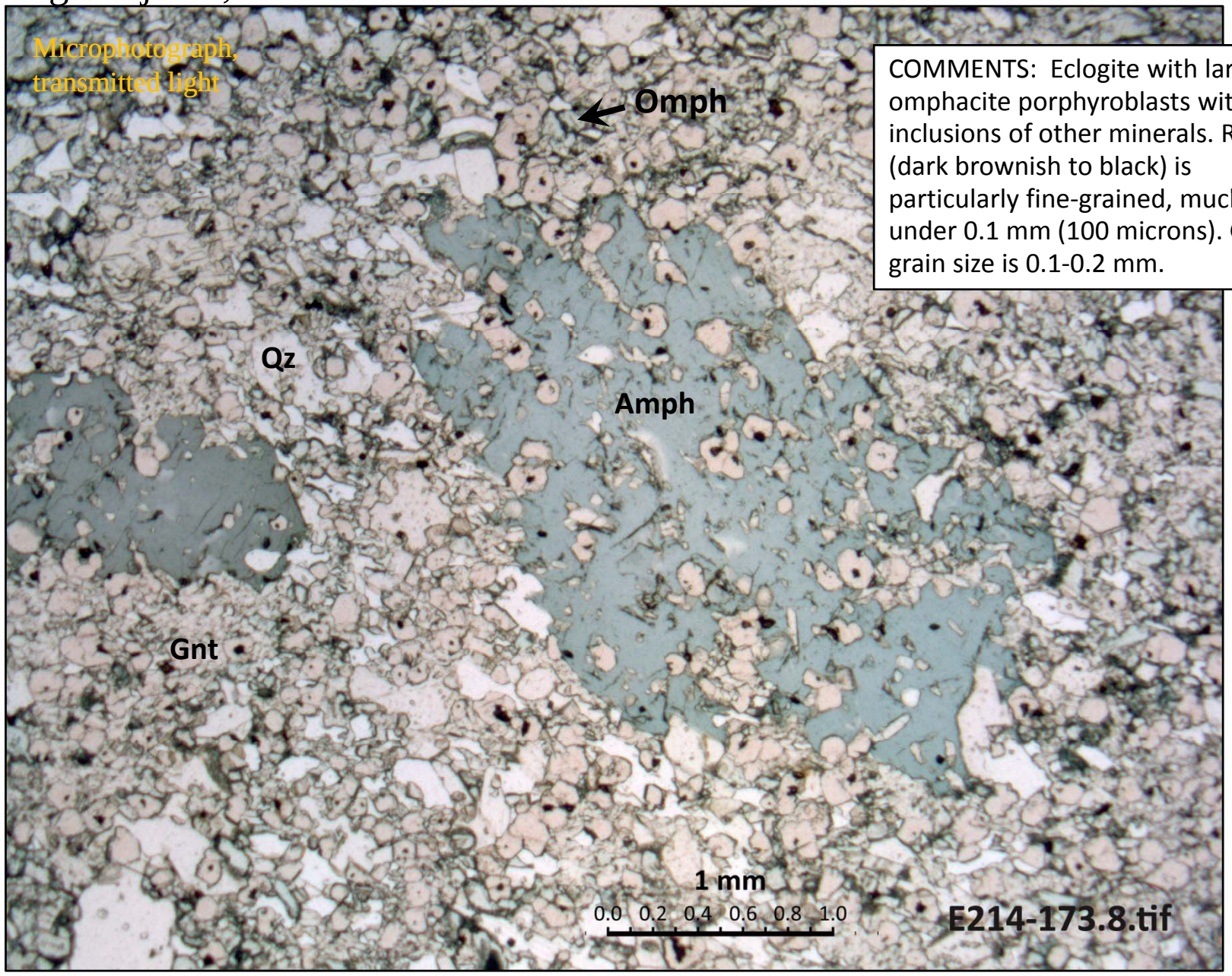
Thin-section Dh205/173.8m

Comments

Fine-grained eclogite with large amphibole porphyroblasts.

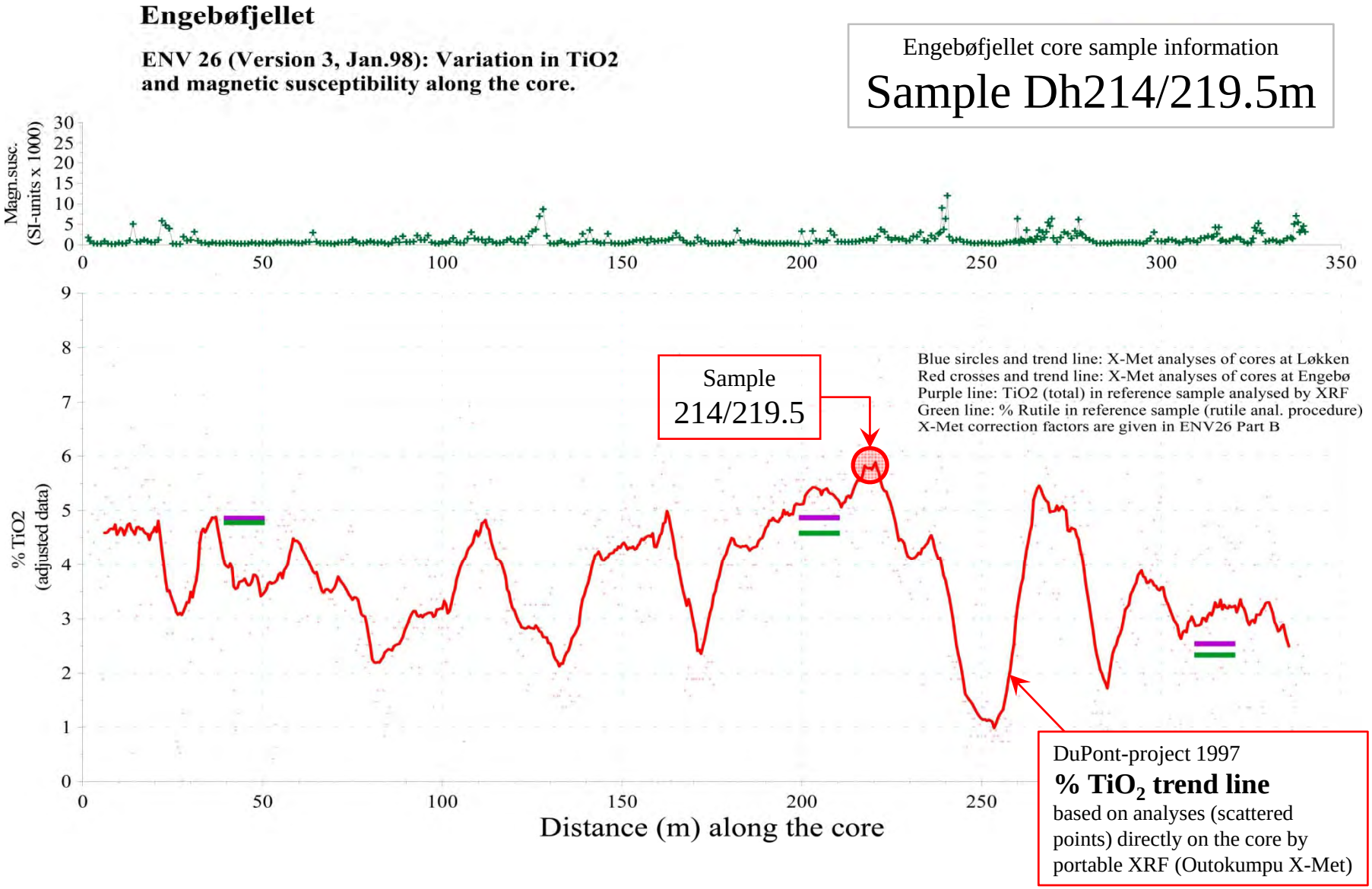


Engebøfjellet, Bh214/173.8m



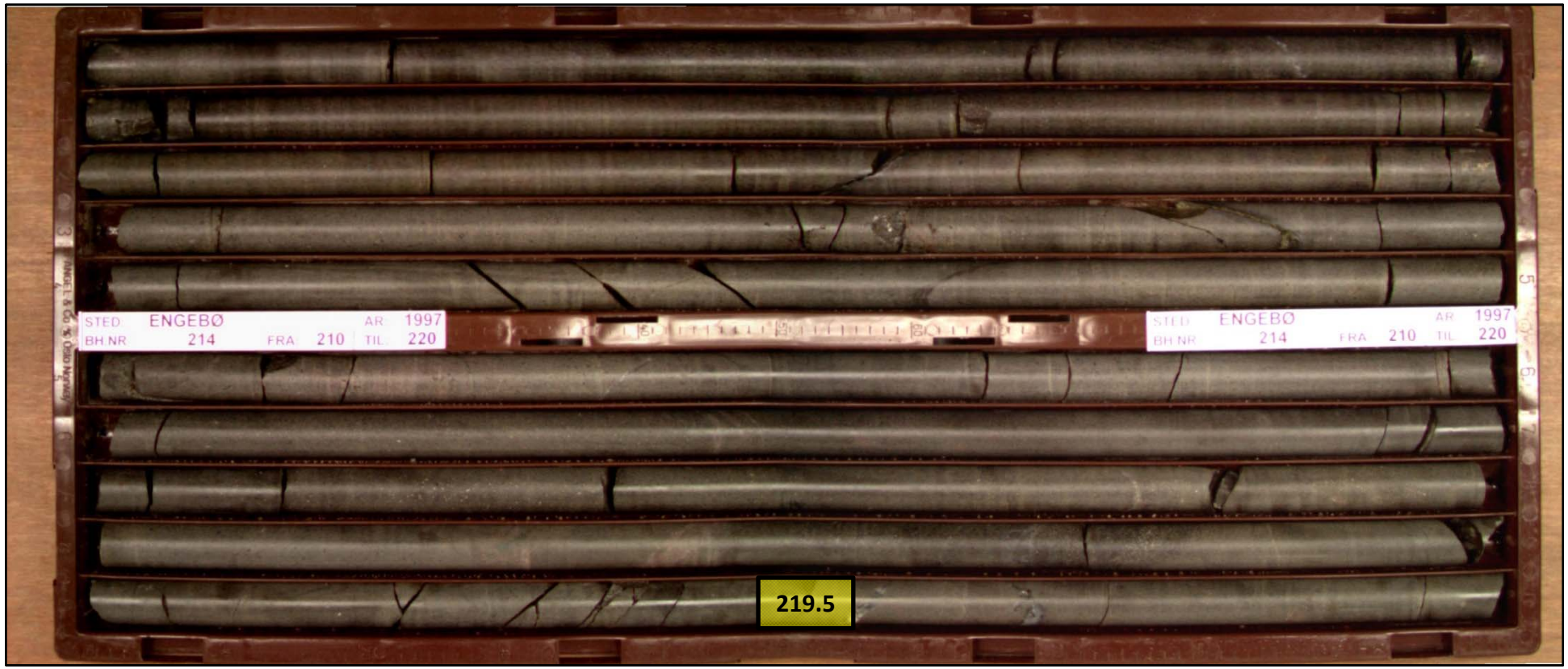
COMMENTS: Eclogite with large omphacite porphyroblasts with inclusions of other minerals. Rutile (dark brownish to black) is particularly fine-grained, much under 0.1 mm (100 microns). Garnet grain size is 0.1-0.2 mm.

Dh214

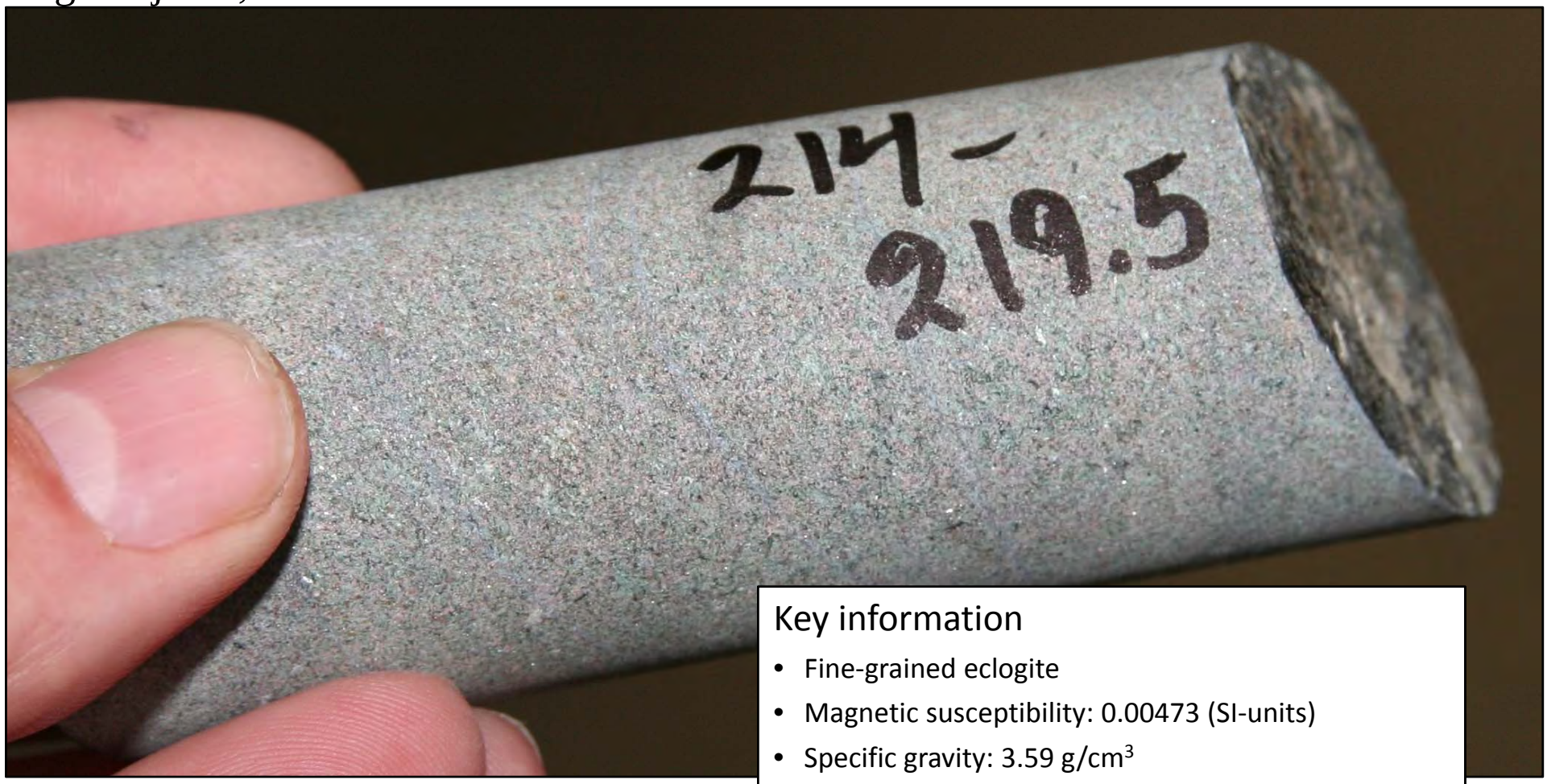

Engebøfjellet
ENV 26 (Version 3, Jan.98): Variation in TiO2 and magnetic susceptibility along the core.
Engebøfjellet core sample information
Sample Dh214/219.5m
Magn.susc. (SI-units x 1000)
% TiO2 (adjusted data)
Sample 214/219.5
Blue sircles and trend line: X-Met analyses of cores at Løkken
Red crosses and trend line: X-Met analyses of cores at Engebø
Purple line: TiO2 (total) in reference sample analysed by XRF
Green line: % Rutile in reference sample (rutile anal. procedure)
X-Met correction factors are given in ENV26 Part B
Distance (m) along the core
DuPont-project 1997
% TiO2 trend line
based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments - 10 m core section

- Digital photo stitched from two low-quality digital photos (DuPont-project 1997).
- Massive eclogite; slightly retrograded along fractures; sample 214/219.5 is probably fairly representative .



Engebøfjellet, Bh214/219.5m



Key information

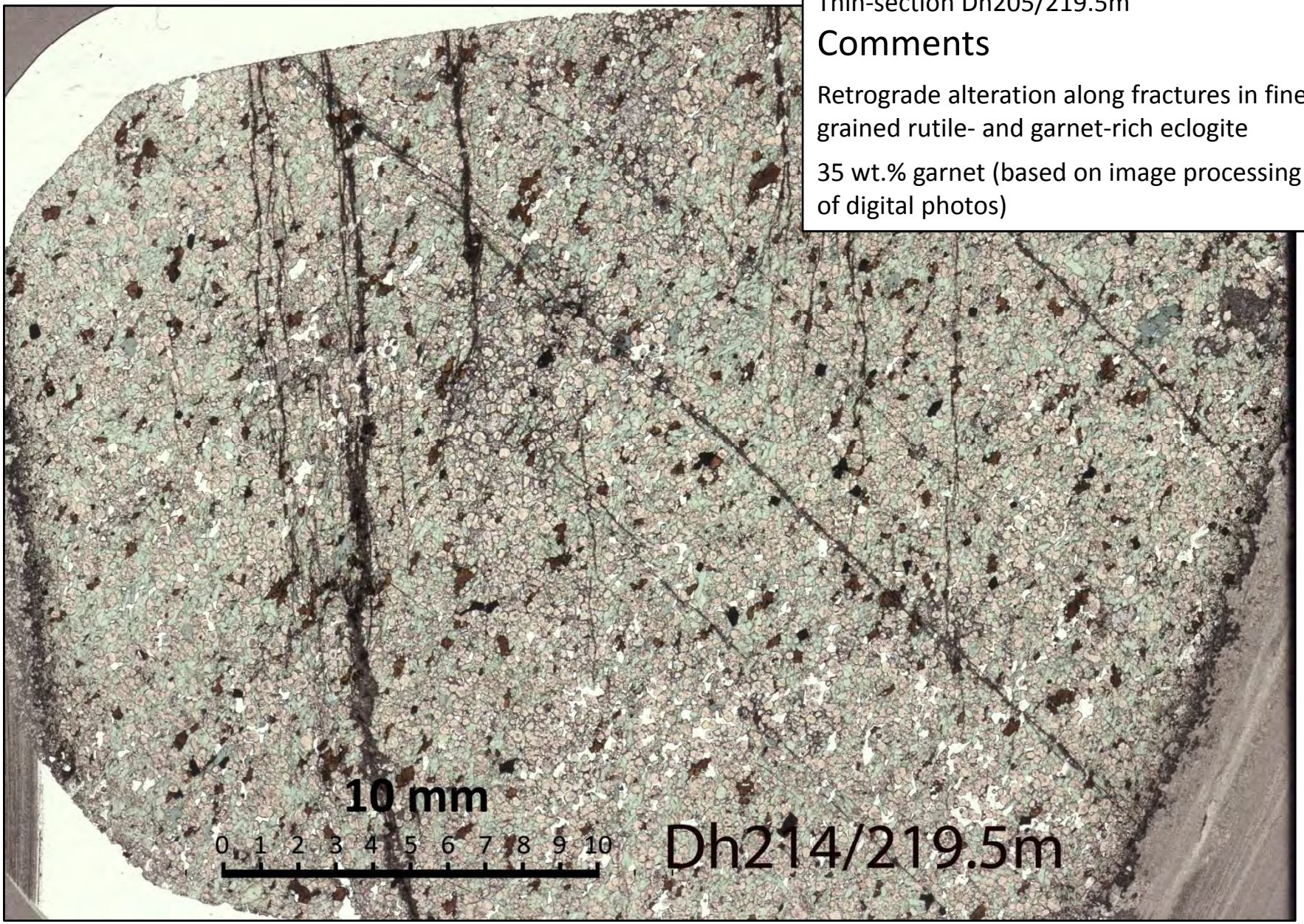
- Fine-grained eclogite
- Magnetic susceptibility: 0.00473 (SI-units)
- Specific gravity: 3.59 g/cm^3
- 2.2 % TiO_2 , 17.9 % Fe_2O_3
  Analysed by Niton portable XRF directly on the sample surface, average value (n=5)

Thin-section Dh205/219.5m

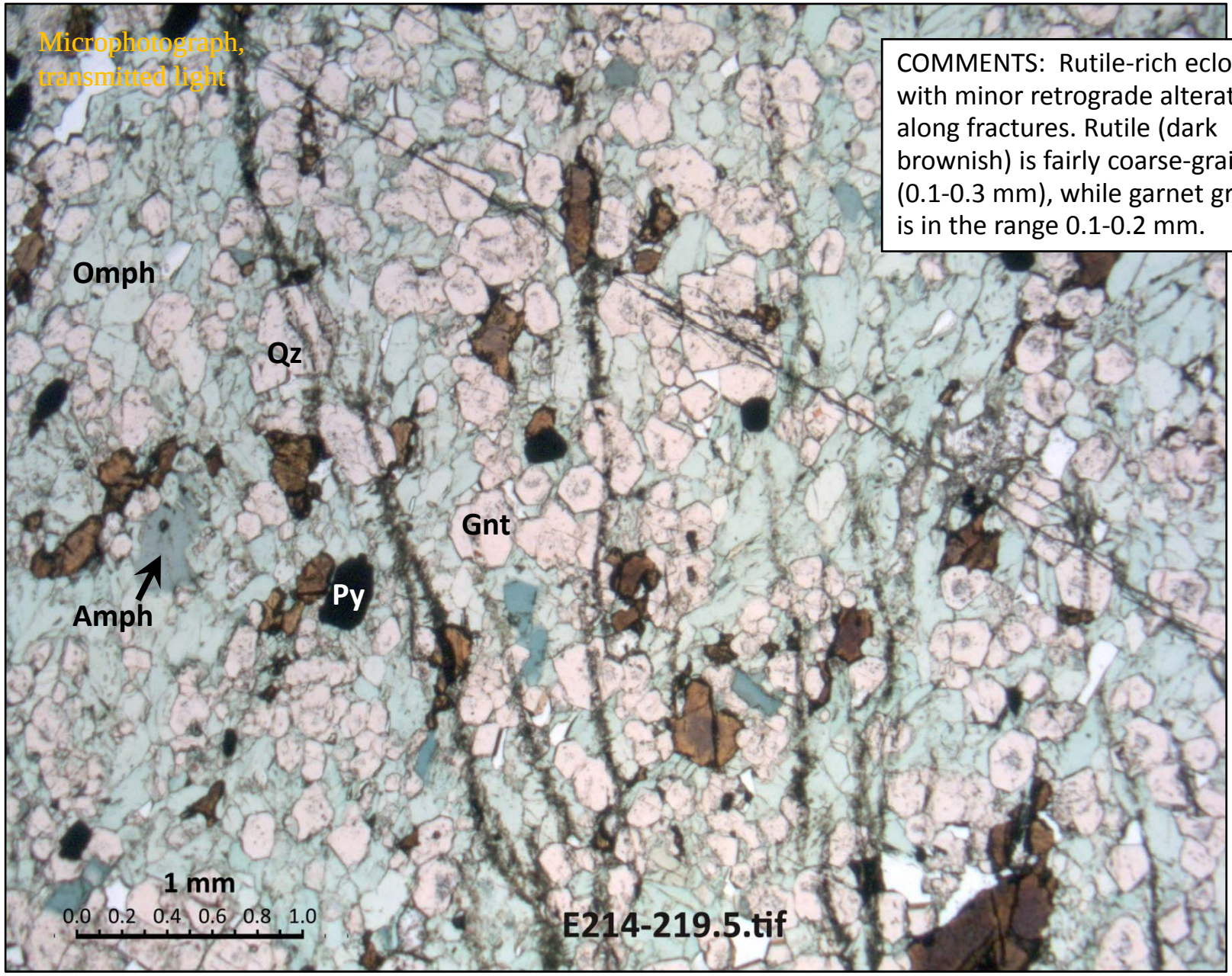
Comments

Retrograde alteration along fractures in fine-grained rutile- and garnet-rich eclogite

35 wt.% garnet (based on image processing of digital photos)



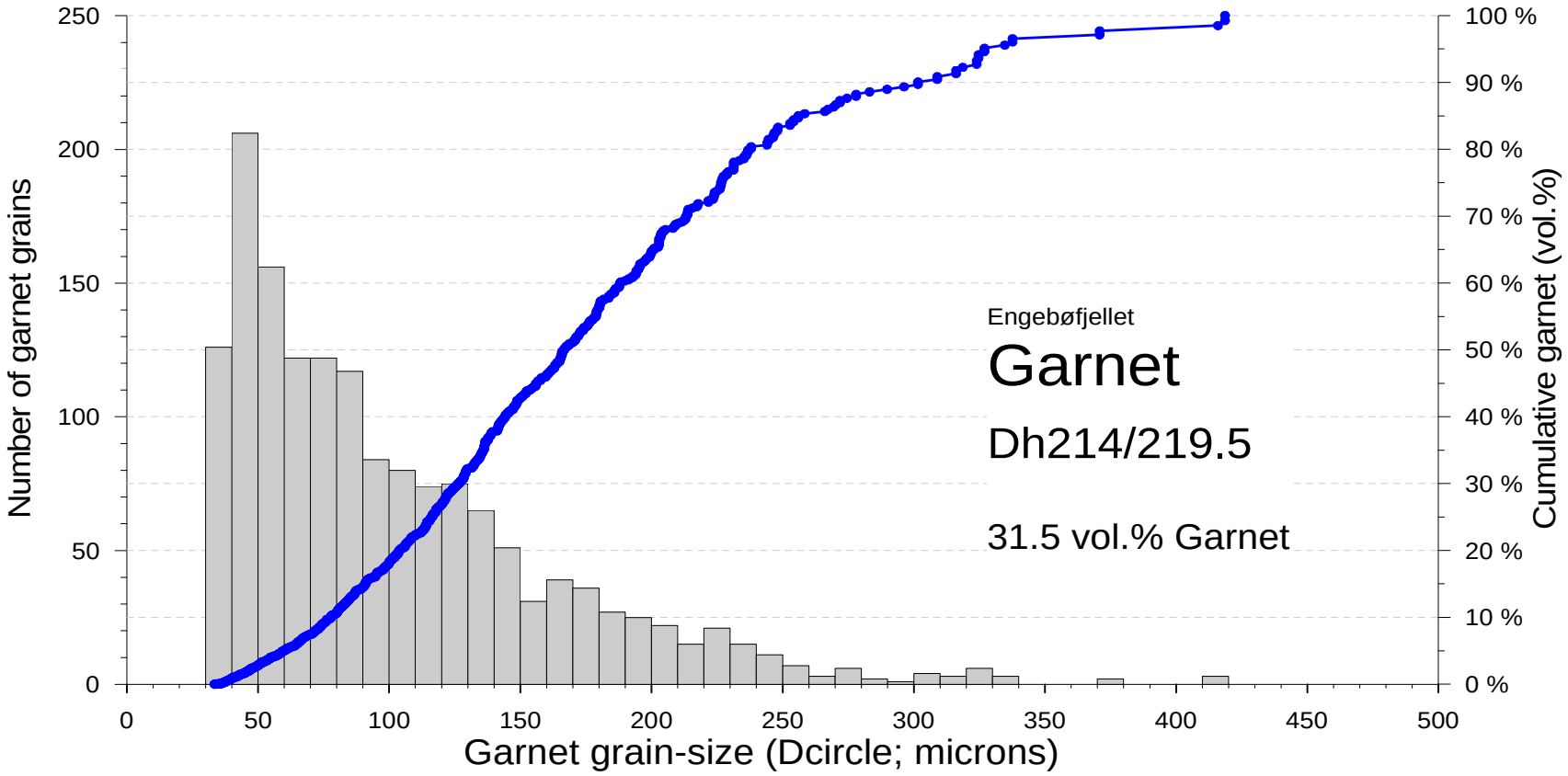
Engebøfjellet, Bh214/219.5m



COMMENTS: Rutile-rich eclogite with minor retrograde alteration along fractures. Rutile (dark brownish) is fairly coarse-grained (0.1-0.3 mm), while garnet grain size is in the range 0.1-0.2 mm.

Comments

Garnet grain-size information plot based on the image processing procedure described in Chapter 6.
The resolution of the present method is low and the finest grains are not picked up. Roughly, in this sample 50 vol. % of the garnet is less than 170 microns. However, since grains attached to each other is registered as one larger grain by this method, the real 50 vol. % boundary is below 170 microns.



Appendix 2:

Table A: Whole-rock XRF major element analyses of Engebøfjellet eclogite based on analyses from the DuPont-project; rutile analysed by "rutile analytical procedure", see description in Korneliussen et al. (2007). Numbers are in wt. % except Rut/TiO_2 that is a ratio.

Sample	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	MnO	P_2O_5	LOI	Sum	Rutil	Rut/TiO_2
1/101-103	45.65	13.47	17.60	3.49	4.70	9.40	2.57	0.52	0.23	1.54	0.12	99.29	3.22	0.92
1/126-127	45.26	13.00	17.95	3.71	4.65	9.55	2.37	0.56	0.23	1.75	0.38	99.42	3.29	0.89
1/65-66	46.24	15.04	16.12	1.81	6.01	9.57	2.77	0.91	0.18	0.23	0.96	99.83	1.71	0.94
2/115-116	44.59	13.67	18.17	4.90	5.49	9.94	2.54	0.27	0.21	0.10	-0.01	99.89	4.65	0.95
2/150-155	44.64	12.85	19.94	3.63	6.14	10.01	2.26	0.25	0.21	0.11	0.01	100.06	3.36	0.93
2/165-170	44.56	13.15	18.02	5.05	5.22	9.76	2.30	0.40	0.21	0.15	0.01	98.83	4.90	0.97
2/200-205	42.59	13.38	18.31	3.52	4.30	9.50	2.23	0.52	0.25	1.51	0.10	96.22	3.14	0.89
3/110-111	50.10	17.40	10.23	0.85	7.61	8.07	2.96	0.70	0.15	0.12	1.85	100.03	0.78	0.92
3/135-136	47.77	16.93	13.95	2.02	4.57	10.19	2.64	0.31	0.13	0.08	0.52	99.10	1.97	0.98
3/15-20	51.10	17.60	9.74	0.88	7.35	8.22	2.47	0.42	0.14	0.11	1.70	99.75	0.84	0.95
3/159-160	43.76	13.53	17.89	5.08	5.78	10.23	2.25	0.21	0.20	0.07	0.21	99.22	4.97	0.98
3/60-65	51.03	18.42	9.54	0.83	6.93	8.48	2.79	0.56	0.14	0.11	1.69	100.51	0.78	0.94
4/106-108	46.37	13.49	16.13	2.99	5.96	10.27	2.25	0.22	0.22	0.08	0.84	98.83	2.88	0.96
4/120-121	43.09	11.29	20.53	5.05	6.55	10.10	1.82	0.08	0.26	0.08	0.26	99.11	3.85	0.76
4/130-131	44.01	11.78	19.73	4.46	6.22	9.87	2.13	0.18	0.25	0.09	0.22	98.95	4.19	0.94
4/151-152	45.51	14.15	17.49	4.41	4.94	9.47	2.51	0.33	0.21	0.11	0.44	99.57	4.14	0.94
4/36-40	45.05	15.22	17.67	2.59	5.96	9.88	2.72	0.27	0.18	0.06	0.17	99.77	2.36	0.91
4/75-77	43.12	13.99	17.98	5.09	5.36	9.81	2.11	0.43	0.21	0.08	0.95	99.13	4.91	0.96
4/97-98	44.68	13.37	17.28	4.44	5.85	10.35	2.26	0.13	0.21	0.08	0.18	98.82	4.34	0.98
10/120-125	45.90	15.39	17.13	2.60	5.85	10.54	2.57	0.22	0.15	0.07	0.22	100.65	2.56	0.98
10/145-150	45.88	13.32	18.64	4.89	6.30	10.22	2.07	0.18	0.21	0.07	-0.07	99.70	4.77	0.98
10/240-245	45.16	13.69	17.39	4.84	5.74	9.86	2.25	0.28	0.20	0.10	0.05	99.57	4.71	0.97
10/290-295	45.53	13.51	16.88	4.70	5.28	9.32	2.05	0.59	0.19	0.08	1.11	99.24	4.52	0.96
11/140-150	44.65	14.07	18.70	2.90	6.06	10.14	1.85	0.29	0.19	0.06	Nd	98.96	2.80	0.97
11/200-210	44.97	13.38	17.16	4.83	5.48	9.81	1.98	0.36	0.19	0.06	Nd	98.17	4.76	0.99
12/270-280	44.71	13.54	17.26	4.98	5.51	10.19	2.07	0.28	0.20	0.08	Nd	98.63	4.91	0.98
12/370-380	45.13	13.59	17.22	4.73	5.18	9.87	1.97	0.39	0.20	0.08	Nd	98.49	4.62	0.98
13/100-105	43.18	12.57	18.43	4.85	5.89	10.12	2.03	0.19	0.20	0.07	Nd	98.31	4.66	0.96
13/130-140	44.01	13.71	18.02	5.06	5.16	9.73	2.02	0.31	0.20	0.07	Nd	98.97	4.99	0.99
13/150-160	43.88	13.40	17.87	4.90	5.49	10.16	2.01	0.23	0.20	0.08	Nd	98.33	4.81	0.98
13/180-181	44.17	13.93	16.62	4.73	4.95	9.50	2.09	0.66	0.18	0.07	Nd	98.37	4.46	0.94
13/182-183	43.40	13.72	17.44	5.10	5.26	9.85	2.05	0.45	0.20	0.07	Nd	98.26	4.95	0.97
13/190-200	44.38	13.01	17.30	4.88	5.75	9.85	1.95	0.43	0.21	0.08	Nd	98.23	4.67	0.96
13/230-240	45.30	13.07	18.42	3.07	5.91	10.12	1.78	0.29	0.19	0.05	Nd	98.85	2.90	0.94
13/257-258	43.80	13.39	18.68	3.16	5.87	9.91	1.87	0.38	0.19	0.07	Nd	98.79	3.08	0.97
13/259.1-260	40.71	13.71	12.18	2.47	5.39	10.22	0.17	2.78	0.15	0.61	Nd	98.17	2.24	0.91
102/10-20	46.91	13.86	16.85	3.47	5.42	9.61	2.62	0.43	0.21	0.13	0.68	100.18	3.16	0.91
102/120-130	47.06	12.98	17.97	2.83	6.31	9.74	2.05	0.38	0.19	0.08	0.62	100.21	2.68	0.95
102/180-190	44.42	12.50	17.13	4.71	6.01	9.70	2.31	0.38	0.20	0.08	0.98	98.41	4.47	0.95
102/250-260	45.00	13.70	17.16	4.64	5.46	9.37	2.63	0.36	0.20	0.09	1.00	99.62	4.08	0.88
103/110-120	43.70	12.87	18.96	3.33	6.61	10.48	2.14	0.30	0.20	0.09	0.77	99.44	3.14	0.94
103/220-230	46.05	13.88	17.33	2.78	6.19	9.94	2.50	0.34	0.18	0.07	1.08	100.34	2.71	0.97
103/360-370	44.73	13.47	17.12	4.65	5.68	9.54	2.45	0.38	0.20	0.10	0.72	99.06	3.88	0.83
103/50-60	50.49	16.78	9.79	0.67	8.32	7.84	2.63	0.48	0.15	0.11	2.36	99.62	0.63	0.94
104/200-210	45.03	14.03	17.80	2.66	6.25	10.12	2.48	0.27	0.18	0.08	0.30	99.19	2.55	0.96
104/330-340	44.28	13.38	19.15	4.31	6.56	10.42	2.31	0.26	0.21	0.08	0.18	101.14	4.03	0.94
104/90-100	43.61	13.56	17.75	4.43	6.07	10.09	2.50	0.41	0.21	0.08	0.51	99.21	4.33	0.98

107/190-200	45.24	13.79	18.65	3.04	6.41	10.06	2.33	0.29	0.20	0.08	-0.20	99.90	2.93	0.96
107/50-60	49.94	14.71	11.19	0.56	11.21	7.36	2.01	0.29	0.18	0.08	1.64	99.16	0.54	0.96
108/130-140	43.81	12.75	19.12	4.23	6.66	10.40	2.24	0.26	0.20	0.07	-0.01	99.74	4.04	0.96
108/200-210	46.29	13.93	17.73	3.03	5.69	9.25	2.59	0.47	0.22	1.07	0.11	100.38	2.68	0.88
108/340-350	44.61	13.14	17.45	5.08	6.05	9.70	2.44	0.42	0.20	0.07	0.01	99.17	4.30	0.85
108/50-60	51.05	19.62	8.55	0.57	7.35	9.09	2.74	0.30	0.13	0.10	1.28	100.78	0.55	0.96
109/140-150	47.96	13.54	15.91	3.88	4.94	8.89	2.74	0.70	0.20	0.14	0.54	99.44	3.73	0.96
109/200-210	44.92	13.42	17.65	5.03	5.39	9.52	2.45	0.41	0.20	0.09	0.45	99.53	4.87	0.97
110/110-120	49.75	14.79	14.49	2.09	5.44	8.89	3.13	0.83	0.15	0.08	0.89	100.52	1.73	0.83
110/170-180	43.95	12.66	17.26	4.95	5.99	10.12	2.46	0.33	0.20	0.09	0.07	98.07	4.77	0.96
110/290-300	44.56	13.26	17.14	5.00	5.36	9.39	2.44	0.50	0.19	0.09	0.66	98.59	4.52	0.90
111/200-210	44.22	13.38	17.47	4.59	5.97	9.87	2.30	0.40	0.20	0.11	0.18	98.69	4.19	0.91
111/330-340	46.07	13.78	16.33	4.26	5.31	9.19	2.74	0.47	0.19	0.11	0.54	99.00	4.09	0.96
111/60-70	50.60	18.48	8.81	0.68	7.25	8.80	2.81	0.35	0.13	0.13	1.27	99.30	0.66	0.97
112/180-190	44.11	13.22	17.20	4.97	5.99	9.87	2.38	0.38	0.20	0.09	0.46	98.87	4.81	0.97
112/260-270	46.78	14.09	16.19	2.41	5.89	9.60	2.55	0.40	0.16	0.09	0.60	98.78	1.83	0.76
112/360-370	45.48	13.48	17.01	4.42	5.75	9.30	2.17	0.74	0.19	0.12	0.26	98.94	4.15	0.94
113/170-180	47.44	11.66	17.86	3.90	4.04	8.32	2.70	0.88	0.24	1.21	0.22	98.48	2.92	0.75
113/240-250	43.99	13.51	18.49	3.00	6.46	9.99	2.50	0.26	0.19	0.10	-0.03	98.45	2.81	0.94
114/100-110	47.27	11.68	17.87	3.85	4.01	8.19	2.88	0.51	0.21	1.22	0.74	98.42	2.13	0.55
202/180-190	48.36	13.19	14.78	2.96	5.75	9.36	2.61	0.37	0.19	1.15	1.03	99.75	2.69	0.91
202/20-30	47.13	13.42	16.55	3.71	5.64	9.78	2.50	0.41	0.21	0.11	0.44	99.90	3.60	0.97
202/70-80	46.31	14.27	17.42	4.01	5.34	9.58	2.59	0.38	0.22	0.13	0.14	100.39	3.90	0.97
203/170-180	49.09	14.21	14.98	2.75	5.21	9.02	2.74	0.66	0.20	0.11	0.58	99.55	2.45	0.89
203/20-30	45.71	14.11	17.04	4.18	5.53	9.24	2.92	0.39	0.21	0.15	1.22	100.70	3.99	0.95
204/10-20	45.47	13.97	17.98	4.19	5.47	9.67	2.58	0.22	0.22	0.12	0.06	99.94	4.03	0.96
204/130-140	47.08	13.05	15.59	3.75	5.58	9.78	2.62	0.40	0.20	0.11	1.35	99.52	3.52	0.94
207/110-120	43.69	12.57	17.99	5.04	6.19	10.21	2.46	0.24	0.21	0.08	0.09	98.76	4.77	0.95
207/130-140	44.21	13.65	17.29	4.96	5.92	9.88	2.36	0.35	0.19	0.09	0.01	98.90	4.71	0.95
207/60-70	44.48	13.74	18.82	3.20	6.31	10.20	2.28	0.33	0.20	0.08	0.10	99.74	3.14	0.98
208/130-140	47.34	13.40	16.28	4.53	5.81	9.35	2.32	0.71	0.19	0.09	0.34	100.35	4.42	0.98
208/270-280	46.78	12.64	17.11	4.72	5.38	9.14	2.32	0.38	0.19	0.10	0.67	99.43	4.44	0.94
208/50-60	46.66	15.41	14.94	2.50	5.58	9.12	2.44	1.10	0.16	0.33	1.30	99.55	2.35	0.94
209/150-160	44.58	13.44	17.61	5.03	5.96	10.17	2.74	0.30	0.19	0.08	0.01	100.13	4.94	0.98
209/90-100	44.61	13.64	18.81	3.18	6.57	10.52	2.27	0.19	0.19	0.08	-0.02	100.02	3.13	0.98
210/100-110	45.92	16.63	15.93	2.46	5.28	10.73	2.63	0.27	0.15	0.08	0.47	100.55	2.40	0.98
210/240-250	44.51	13.58	17.68	4.82	6.25	10.36	2.53	0.25	0.20	0.09	0.27	100.52	4.48	0.93
210/340-350	46.37	14.01	16.25	3.17	5.87	9.37	2.64	0.54	0.21	0.15	0.90	99.47	2.96	0.93
211/130-140	47.56	11.49	17.77	3.80	4.00	7.89	2.44	1.05	0.25	1.20	0.73	98.19	2.02	0.53
211/210-220	44.84	13.64	16.92	4.34	5.26	9.63	2.64	0.38	0.21	0.14	0.30	98.30	3.90	0.90
211/310-320	43.06	12.96	17.80	5.03	5.87	9.82	2.37	0.31	0.20	0.12	0.48	98.03	4.85	0.96
211/410-420	44.34	13.29	17.08	4.31	6.06	9.88	2.35	0.43	0.21	0.12	0.65	98.71	3.40	0.79
212/170-180	45.76	14.13	16.44	4.12	5.39	9.61	2.72	0.39	0.21	0.14	0.11	99.03	3.91	0.95
212/270-280	46.90	13.82	15.68	3.68	5.11	8.45	2.53	0.72	0.19	0.13	1.07	98.27	3.40	0.92
212/70-80	44.15	13.46	17.20	4.90	6.02	10.10	2.42	0.25	0.19	0.10	-0.13	98.67	4.81	0.98
213/130-140	46.01	14.49	14.49	2.29	6.17	9.43	2.79	0.59	0.20	0.22	2.58	99.26	2.16	0.94
213/210-220	46.74	13.48	16.05	3.31	5.34	9.48	2.55	0.52	0.21	0.13	1.33	99.13	3.01	0.91
213/40-50	43.86	13.13	17.57	4.88	5.71	9.93	2.42	0.37	0.21	0.12	0.17	98.37	4.67	0.96
214/200-210	43.74	12.35	18.94	4.87	6.07	9.94	2.26	0.15	0.24	0.13	-0.03	98.65	4.59	0.94
214/310-320	45.73	14.22	14.37	2.54	5.84	9.29	2.80	0.87	0.19	0.56	2.37	98.78	2.33	0.92
214/40-50	44.46	13.60	17.15	4.86	5.92	10.28	2.47	0.27	0.20	0.12	0.03	99.36	4.78	0.98
301/100-110	44.38	14.25	18.34	2.68	6.51	10.42	2.36	0.20	0.18	0.08	0.33	99.73	2.60	0.97
301/190-200	44.70	13.79	17.34	4.21	5.34	9.73	2.56	0.28	0.22	0.71	0.41	99.30	4.10	0.97
301/40-50	43.94	12.91	18.24	4.87	6.19	9.75	2.27	0.28	0.20	0.09	0.21	98.95	4.76	0.98
302/190-200	43.53	12.96	17.69	5.06	6.31	10.19	2.29	0.21	0.21	0.10	0.22	98.76	4.84	0.96

302/30-40	44.74	13.58	16.83	4.51	5.90	9.79	2.50	0.43	0.19	0.09	0.47	99.02	4.43	0.98
302/330-340	43.82	13.52	18.05	5.14	5.65	9.88	2.33	0.32	0.21	0.11	-0.15	98.88	4.98	0.97
303/140-150	44.75	13.30	17.66	4.42	6.02	9.62	2.28	0.31	0.21	0.33	0.12	99.01	4.30	0.97
303/230-240	47.56	13.81	15.74	3.35	5.51	9.10	2.69	0.52	0.19	0.13	0.67	99.28	3.22	0.96
303/40-50	44.55	13.16	18.45	3.80	6.29	10.06	2.29	0.30	0.21	0.11	0.11	99.34	3.71	0.98
303/90-100	44.23	13.70	18.54	2.89	6.54	10.31	2.35	0.26	0.18	0.08	0.28	99.36	2.74	0.95
304/200-210	44.31	13.55	17.24	4.85	5.89	9.97	2.50	0.34	0.20	0.13	-0.11	98.86	4.65	0.96
304/330-340	44.39	13.34	17.72	3.55	5.54	9.65	2.58	0.33	0.23	1.42	0.13	98.87	3.33	0.94
304/80-90	44.49	14.00	18.42	2.87	6.46	10.28	2.42	0.25	0.19	0.10	-0.02	99.46	2.81	0.98

Table B: Whole-rock XRF trace-elements and sulphur (leco) analyses of Engebøfjellet eclogite based on analyses from the DuPont-project. Numbers in ppm except S_{leco} that is in %.

Sample	Y	Zr	Nb	Sr	Rb	Ba	Cu	Zn	Pb	Sc	V	Ni	Cr	Ga	Yb	Co	Ce	S_{leco}
1/101-103	48	82	8	294	17	170	26	166	11	38	206	15	44	25	-10	43	75	0.13
1/126-127	49	83	-5	288	16	174	27	165	17	30	207	11	9	26	-10	51	82	0.14
1/65-66	39	119	-5	256	24	401	83	136	12	42	379	72	51	26	-10	51	51	0.14
2/115-116	23	77	-5	119	-5	94	29	143	-10	48	404	15	69	27	-10	58	46	0.15
2/150-155	22	58	-5	135	-5	96	42	158	-10	50	597	17	48	30	-10	68	40	0.24
2/165-170	26	79	-5	139	11	123	26	135	-10	47	406	12	36	27	-10	60	44	0.18
2/200-205	48	66	6	250	14	158	28	163	-10	36	178	10	23	27	-10	48	88	0.12
3/110-111	16	54	-5	307	26	256	40	92	-10	25	129	87	287	17	-10	45	13	0.12
3/135-136	11	44	-5	285	8	115	68	87	-10	34	554	56	56	25	-10	54	22	0.15
3/15-20	17	56	-5	369	7	134	24	83	-10	19	130	84	261	19	-10	39	-10	0.05
3/159-160	11	37	-5	70	-5	84	29	128	-10	51	474	15	108	24	-10	64	38	0.17
3/60-65	15	41	-5	327	14	186	37	76	12	17	128	76	280	22	-10	40	-10	0.35
4/106-108	18	38	-5	237	-5	77	21	122	-10	47	338	18	68	25	-10	54	16	0.18
4/120-121	20	50	-5	81	-5	37	36	149	-10	56	399	26	29	24	-10	68	49	0.20
4/130-131	20	48	6	319	-5	60	46	159	-10	52	341	24	45	25	-10	64	24	0.31
4/151-152	17	57	7	117	6	110	45	131	-10	46	266	15	16	29	-10	55	42	0.07
4/36-40	17	26	-5	144	7	84	42	130	-10	44	572	28	103	25	-10	75	24	0.20
4/75-77	16	44	-5	163	12	115	38	127	-10	49	433	19	19	25	-10	66	35	0.13
4/97-98	19	37	-5	194	-5	53	30	125	-10	50	355	14	74	24	-10	63	25	0.19
11/140-150	17	29	-3	168	5	83	33	132	-5	49	612	24	109	26	-5	67	24	
11/200-210	15	41	-3	145	8	105	27	115	-5	56	477	19	31	25	-5	59	25	
12/270-280	16	49	-3	178	5	92	26	121	-5	57	430	15	65	28	-5	53	33	
12/370-380	17	55	-3	226	9	114	27	126	-5	47	415	21	62	25	-5	52	39	
13/100-105	15	40	-3	152	3	60	34	140	-5	60	510	17	115	26	-5	65	35	
13/130-140	14	50	7	170	9	90	27	126	22	60	435	16	22	25	-5	57	35	
13/150-160	18	44	5	168	3	73	21	130	22	57	442	18	28	25	-5	58	28	
13/180-181	15	46	6	268	21	167	29	116	-5	52	430	16	26	28	-5	52	29	
13/182-183	17	45	-3	194	13	122	21	126	-5	59	434	16	42	22	-5	57	21	
13/190-200	16	48	-3	222	12	114	30	125	-5	60	429	14	18	27	-5	57	27	
13/230-240	15	26	-3	207	6	87	33	128	-5	55	599	18	59	25	-5	67	28	
13/257-258	13	32	-3	192	10	152	36	137	-5	51	618	26	29	22	-5	71	37	
13/259.1-260	25	190	6	688	89	1113	12	71	54	33	547	53	96	28	-5	28	206	