NGU Report 2008.085

Rutile ore characteristics,
Engebøfjellet

NGU
Norges geologiske undersøkelse
Geological Survey of Norway

Geological Survey of Norway
NO-7441 Trondheim, Norway
Tel.: 47 73 90 40 00

REPORT

<table>
<tr><td colspan="2">Report no.: 2008.085</td><td>ISSN 0800-3416</td><td colspan="2">Grading: Confidential until 31.12.2011</td></tr>
<tr><td colspan="5">Title:
Rutile ore characteristics, Engebøfjellet</td></tr>
<tr><td colspan="2">Authors:
Korneliussen, A.</td><td colspan="3">Client:
Nordic Mining ASA</td></tr>
<tr><td colspan="2">County:
Sogn og Fjordane</td><td colspan="3">Commune:
Naustdal</td></tr>
<tr><td colspan="2">Map-sheet name (M=1:250.000)
Måløy</td><td colspan="3">Map-sheet no. and -name (M=1:50.000)
1217.1 Dale</td></tr>
<tr><td colspan="2">Deposit name and grid-reference:
Engebøfjellet
UTM-koord. 310200 E, 6822750 N (EUREF89, zone 32)</td><td colspan="3">Number of pages: 74 Price (NOK): kr 616,-
Map enclosures:</td></tr>
<tr><td>Fieldwork carried out:</td><td>Date of report:
16.12.2008</td><td>Project no.:
263101</td><td colspan="2">Person responsible:
for R. Boyd Jan S. Sandstad</td></tr>
</table>

Summary:

During the DuPont/Conoco/NGU Engebøfjellet project (1995-97) 49 boreholes were drilled, altogether 14527 meters. All cores were analysed for TiO_2 and Fe_2O_3 using a portable XRF instrument (Outokumpu X-Met); approximately 50.000 X-Met analyses were made.

A number of core sections, for most of the drill holes one 10m-section per 100m core, were also analysed in the laboratory by a combined XRF and ICP-AES "rutile analytical procedure" in which rutile was determined as the difference between TiO_2 (total, analysed by XRF) and TiO_2 (acid soluble, analysed by ICP-AES), giving precise information about total whole-rock TiO_2 and other major elements, and semi-quantitative information of the amount of rutile present.

The X-Met (XRF) core analyses in combination with surface analyses were the basis for a 3D-model ore resource developed by DuPont.

Evaluation of the analytical data from the DuPont-project confirms that the core analyses carried out by the X-Met portable XRF are semi-quantitative. Adjusted X-Met data based on comparison with reference XRF analyses, give a correct overall picture of the TiO_2-distribution along the cores as well as providing reliable average numbers for large core sections, but they are not reliable on meter-scale and are only indicative on 10-meter scale.

Retrograde alteration of eclogite tends to alter rutile to ilmenite. In general, the rutile/TiO_2-ratio is ≥ 0.9, roughly indicating that more than 90% of the titanium in the rock occurs as rutile.

For prioritised parts of the deposit, i.e. those parts that are planned to be mined, further analytical work on the cores is necessary, i.e. rutile-procedure analyses of rutile ore-type eclogite in 5m-sections combined with SEM-based quantification of rutile and garnet mineral characteristics.

Keywords: Mineral resource	Industrial mineral	Eclogite
Rutile		

Rutile-ore characterisation, Engebøfjellet

Contents

Appendix

1. INTRODUCTION

The Engebøfjellet rutile/eclogite deposit was investigated by DuPont/Conoco in collaboration with NGU in the period 1995-97; in this project NGU's role was mainly to provide geological information about the deposit. All mineral processing and 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 and information obtained during the DuPont project.

The purpose of this report is to summarise and evaluate the available information relevant to rutile.

2. PREVIOUS INVESTIGATIONS

The geological characteristics of the Engebøfjellet rutile deposit was summarised by Korneliussen et al. (2007). The eclogite mineralogy 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. Structural data is provided by Dr Alvar Braathen in the same report.

When DuPont closed the Engebøfjellet project at the end of 1997, a large amount of information was compiled (Korneliussen 1998) with practically all analytical data available at NGU, including core analyses, a variety of graphical print-outs, microphotographs and an updated geological map. The analytical and core-log data were stored in an Access database (Englog.mdb), which was a part of that report.

See also Korneliussen and Raaness (2005) that is an Engebøfjellet presentation available on www.ngu.no.

Garnet in the Engebøfjellet deposit has recently been described by Korneliussen et al. (2008). The rutile and garnet reports are complementary and basic information about the character of the deposit is included in both. Microphotograph and SEM-image documentation of the rock's character provided by the garnet report is highly relevant also for the rutile report. These two reports should therefore be studied together.

3. ECLOGITE MINERALOGY

This chapter is based on the garnet report to Nordic Mining (Korneliussen et al. 2008); new samples taken from old cores in 2008 are described in detail in Appendix 1 in that report. This information gives extensive visual mineralogical-textural information about Engebøfjellet garnet as well as the characteristics of the rutile.

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

- On average, eclogites from Engebøfjellet are fine-grained rocks either as a result of strong eclogite-facies deformation or lack of complete recrystallisation.
- Textures observed in Engebøfjellet eclogite are characteristic of those displayed during the transitions 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 of 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

- In mafic eclogites (ferro-eclogite, i.e. the rutile ore eclogite) modal abundance of garnet ranges from 25-30 to 40-45 % (by volume, visual estimate), while in the leuco-eclogite 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.
- In many garnets inclusions are common (most commonly carbonate, rutile, quartz, omphacite and amphibole). Small garnets (less than 0.2 mm) tend to have many fewer inclusions than the larger garnets.
- The garnet is almandine-rich and often chemically zoned, reflecting incomplete chemical homogenisation during eclogitisation; rim compositions are highest in almandine component (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 a major constituent of the eclogite rock, ranging from traces to major amounts (up to 40 % by volume, visual estimate). Porphyroblasts are common in leuco-/transitional eclogites and include garnet, omphacite, rutile, mica, clinozoisite and carbonate. Composition range from subcalcic actinolitic hornblende to barroisite.
- Phengite and paragonite (white micas) are characteristic of leuco- and transitional eclogites, but minor/trace amounts are also found in mafic eclogites.
- Clinozoisite/epidote are abundant in the matrix of leuco-eclogites and occasionally in the mafic eclogites.
- Carbonate (dolomite/ankerite) are common minor phases 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 from alteration of rutile during retrograde alteration, and is usually intergrown with rutile.
- Pyrite is common as an accessory (less than 1 wt. %) mineral, as disseminated grains, particularly in ferro-eclogite.
- Apatite is a common accessory mineral.
- Zircon is found, rarely, as tiny inclusions in rutile and garnet.

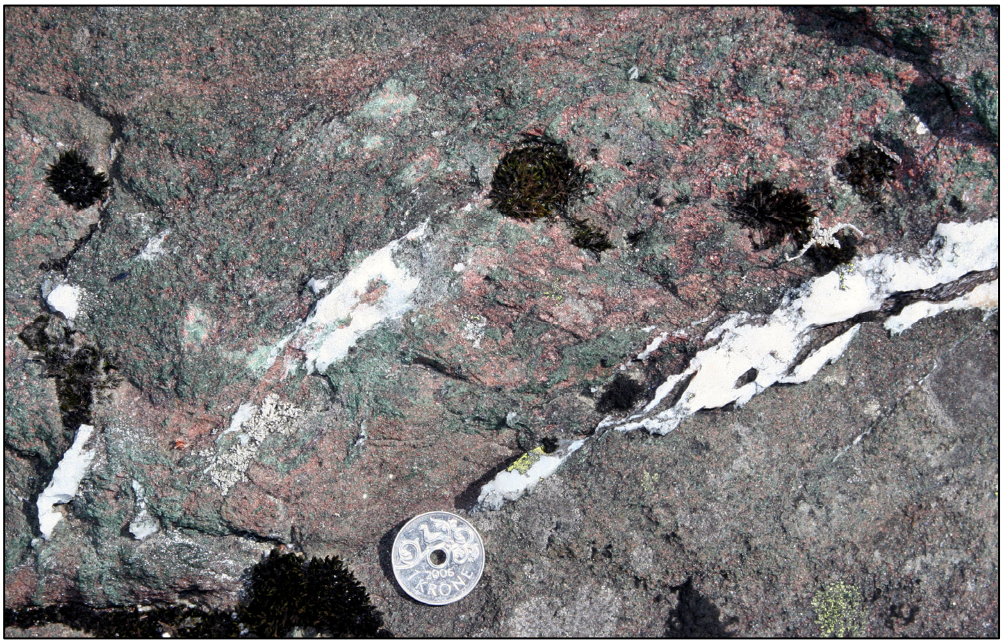
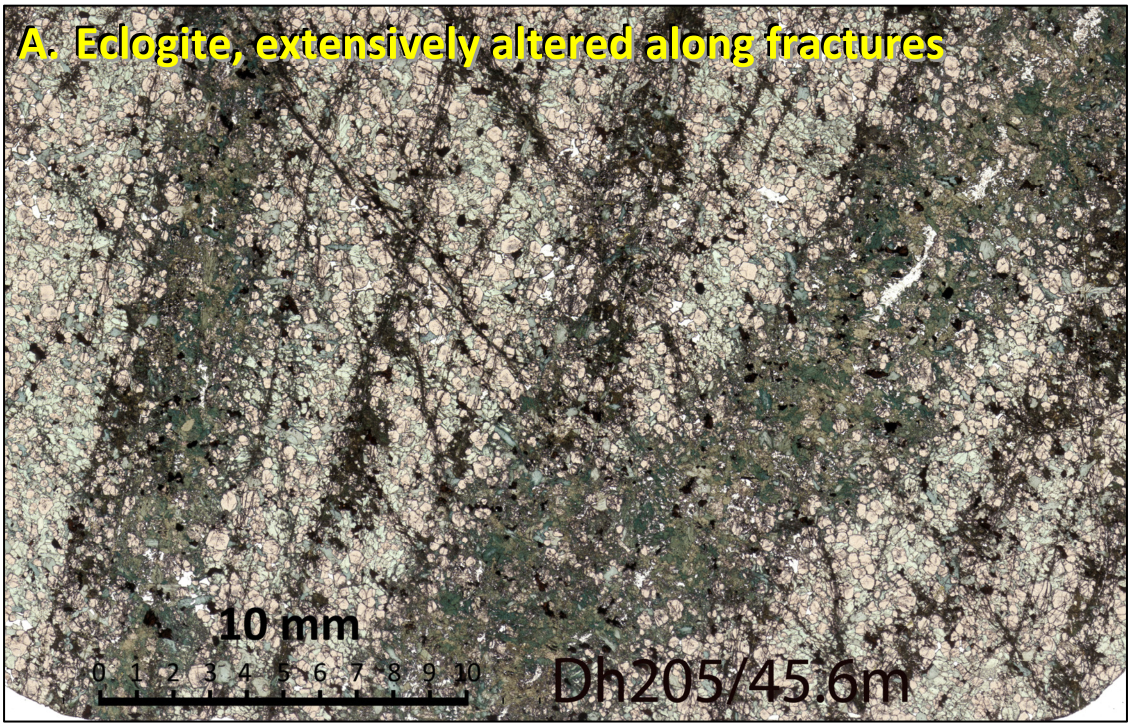


Fig. 1: Fairly heterogeneous rutile ore-type eclogite with quartz-veins.

Fig. 2: Photos of fractures in eclogite (rutile ore type) with 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.



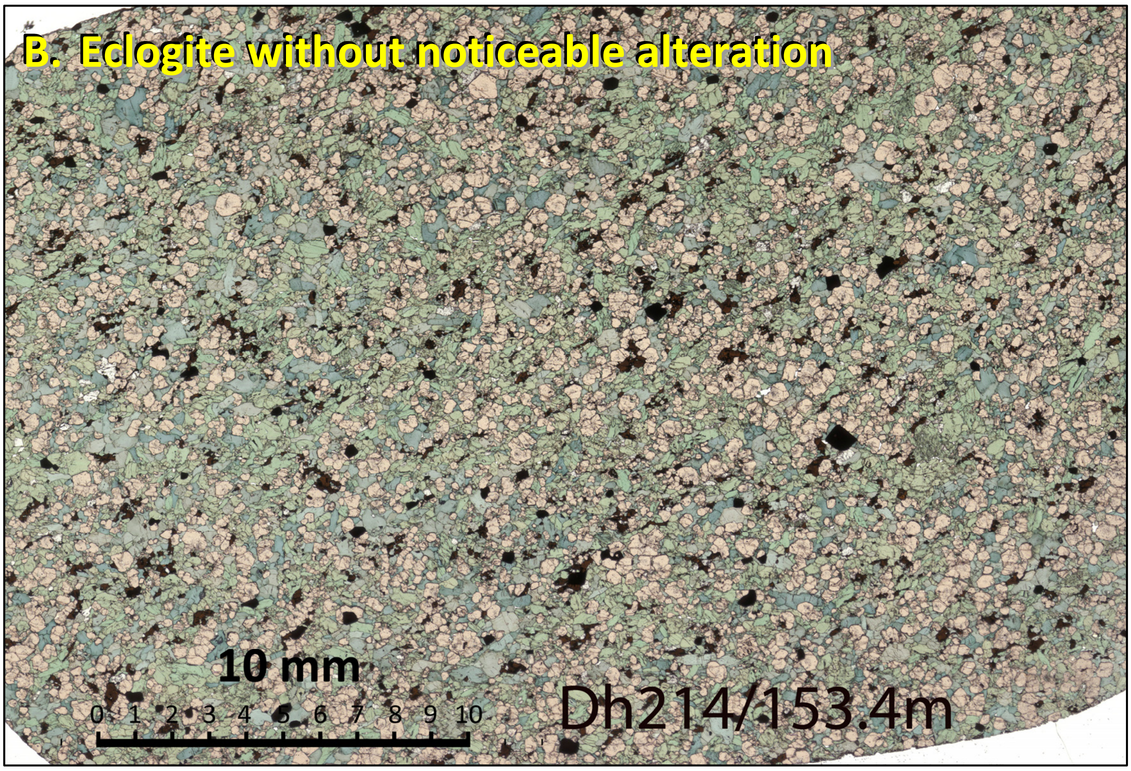


Fig. 3: Thin-section images. Fig A: Extensively altered eclogite (ore type) along the type of fractures illustrated in Fig. 3. Fig. B: Eclogite without noticeable alteration. When considering rutile-rich eclogite in general the volume-portion of not-significantly retrograded eclogite is by far more common than heavily retrograded eclogite.

4. RUTILE ORE CHARACTERISTICS

The character of rutile shown in Fig. 4 is believed to be representative for large volumes of rutile-ore eclogite. Rutile is interstitial to garnet and other silicate minerals, fingering in between the silicates, with highly variable grain-size, although generally fine-grained, often 100-200 microns (0.1-0.2 mm) and less.

Extensive visual documentation of rutile characteristics are given in Appendix 3, as well as in Appendix 1 in the complementary garnet report (Korneliussen et al. 2008).

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

During retrograde alteration of eclogite rutile tends to alter to ilmenite; such altered rutile is shown in Fig. 5. In general the overall effects of retrograde alteration are believed to be minor, i.e. a relatively small amount of the rutile present has gone to ilmenite.

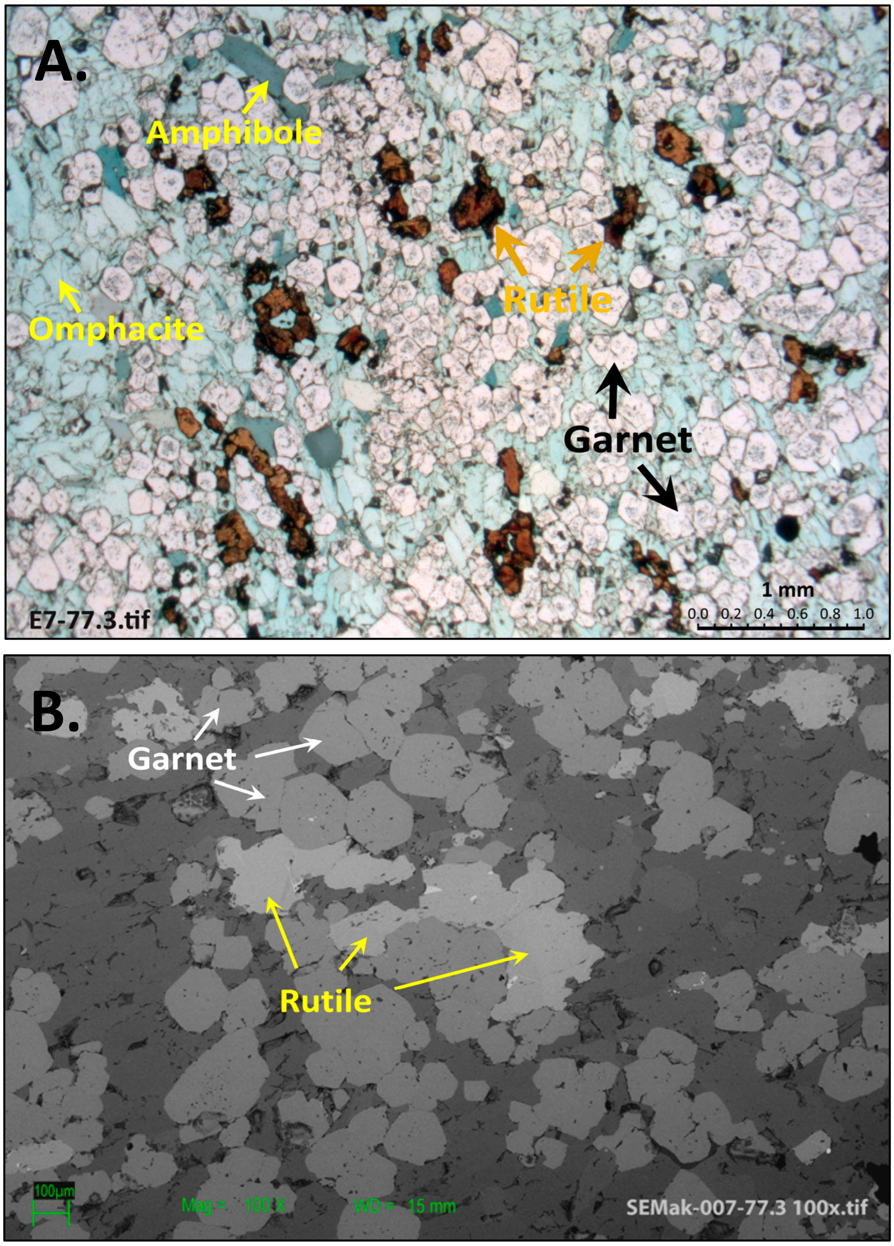
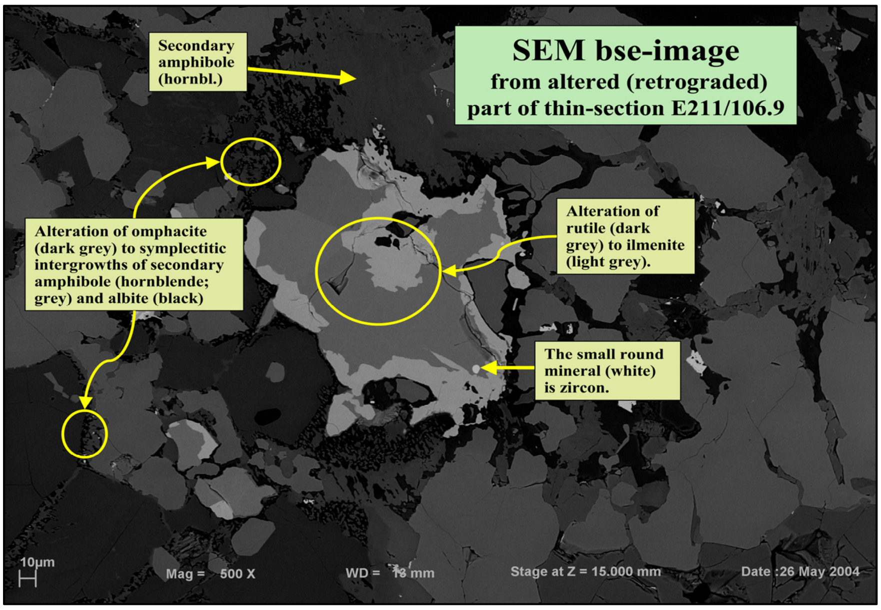


Fig. 4: Rutile- and garnet-rich eclogite. (A) Microphotograph, transmitted light; (B) SEM back-scattered electron image.



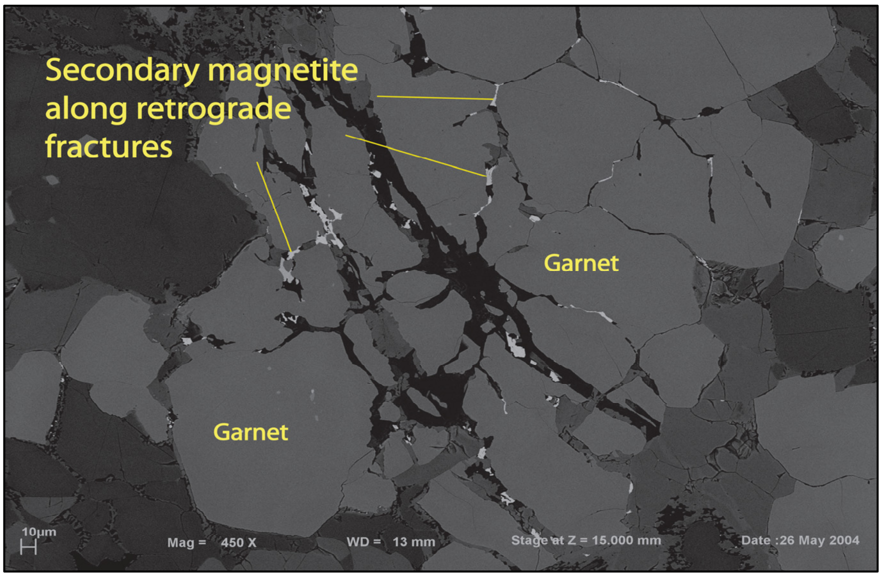


Fig. 5: SEM back-scattered electron image of retrograde altered eclogite with extensive alteration of rutile to ilmenite (upper image). The lower SEM-image show secondary magnetite along fractures in garnet-rich retrograde eclogite. These two images are from the Engebø-fjellet Web-presentation available at www.ngu.no.

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. More than 100 core samples, usually 10m core sections were analysed by combined XRF and ICP-AES (acid soluble); see the complete analytical data in Appendix 1. Acid soluble TiO_2 indicates ilmenite (a detailed description of the method is available from NGU on request) while rutile and silicates are not soluble in this method.

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

This method is semi-quantitative since it does not take into account $TiO_{2\ \text{silicate}}$. For practical purposes the analytical consequences of $TiO_{2\ \text{silicate}}$ (~ 0.1 % TiO_2) are regarded to be negligible.

Fig. 6 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". Depending on mineral processing as well as other factors, it might well be that this limit has been set too low or too high. The Y-axis shows the Rutile/TiO_2-ratio; for samples plotting close to the Rutile/TiO_2=1 line, effects of retrograde alteration on rutile are minor. As samples plot away from this line alteration effects on rutile become larger.

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.

Since retrograde alteration tends to alter rutile to ilmenite at the same time as secondary magnetite is formed (Fig. 5), high magnetic susceptibility is expected at reduced Rutile/TiO_2 (increased ilmenite content). However, no such correlation has been observed.

The explanation might be as follows: (1) Commonly, retrograde alteration along fractures in the eclogite affects only a relatively small volume of the rock and only a small portion of the rutile in that altered parts are actually transformed into ilmenite. In many cases the total rutile-to-ilmenite alteration effect might be practically negligible. For example, if 10% of the sample is affected by alteration and 20% of the rutile in the effected portion has been altered to ilmenite, then altogether only 2 % of the rutile present in the sample has gone to ilmenite (0.1 x 0.2= 0.02). That would be only weakly detected in the rutile analyses, and is regarded as "minor alteration" in Fig. 5, while at "significant alteration" rutile/TiO_2 is roughly between 0.93 and 0.83, and "major alteration" less than 0.83.

(2) The amount of secondary magnetite formed in the relatively small portion of the eclogite sample that is actually altered is sufficient to give a strong magnetic effect since magnetite is an extremely magnetic mineral compared with the other minerals present.

Consequently, increased magnetic susceptibility effectively indicates the presence of retrograde alteration but does not tell how large a portion of the rutile has been transformed into ilmenite.

Thus, magnetic susceptibility can be a useful tool in mapping the distribution of retrograde alteration zones throughout the deposit, but not to quantify the rutile-to-ilmenite transformation.

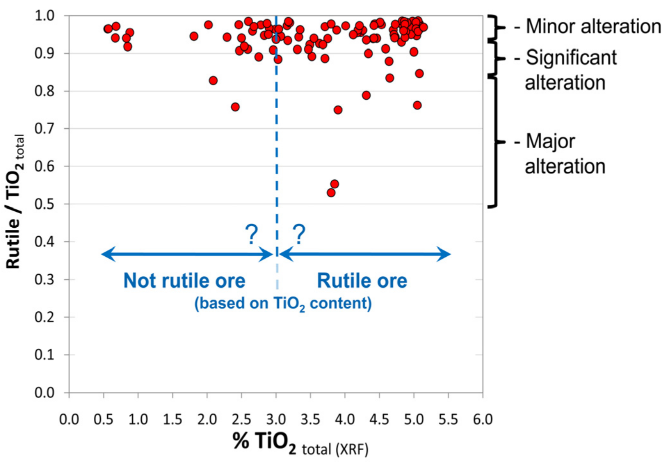


Fig. 6: TiO_2-rutile relationships and the effects of retrograde alteration on rutile/TiO_2-ratio, based on data in Appendix 1.

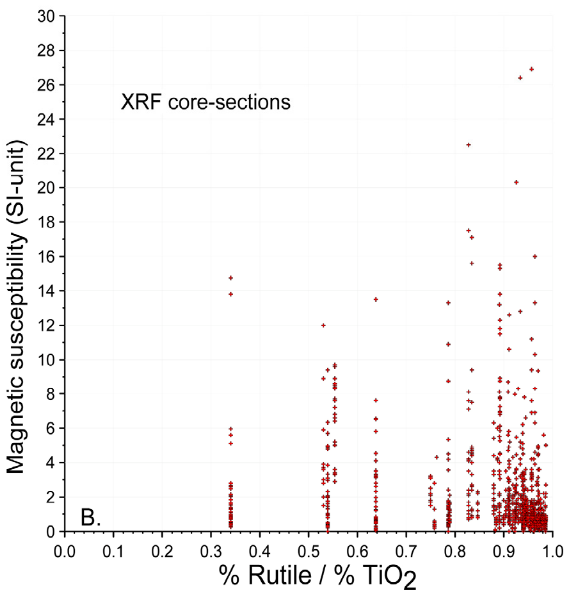
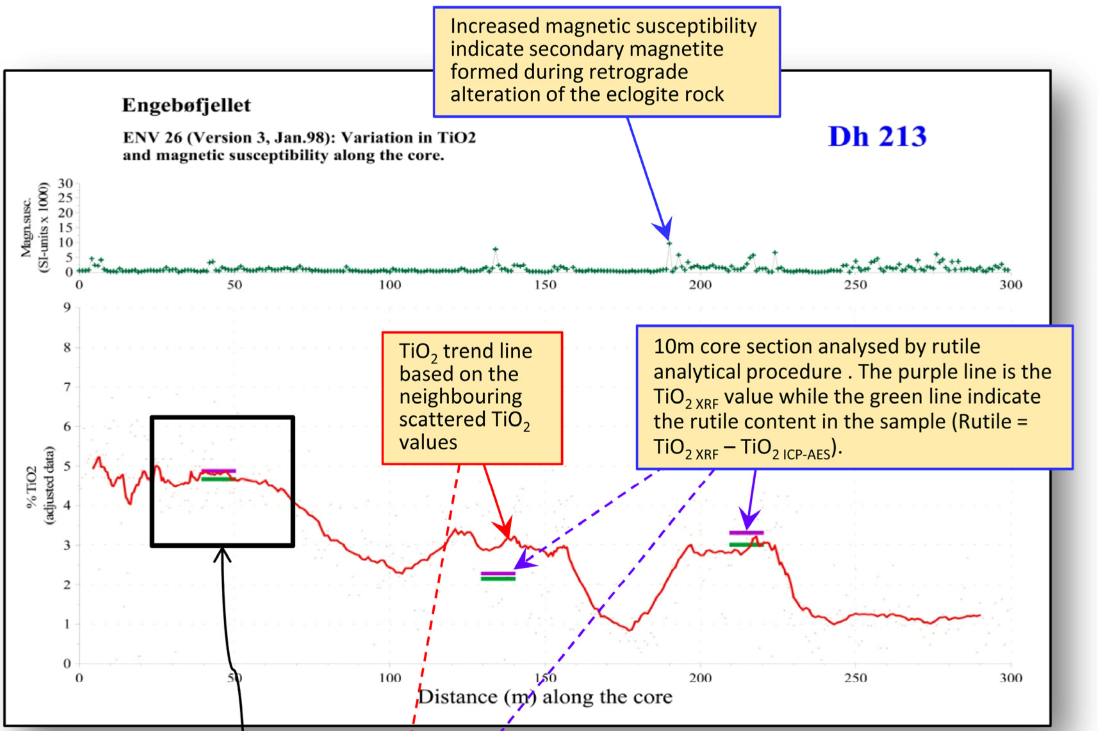


Fig. 7: Rutile/TiO_2 vs. magnetic susceptibility.

All cores were analysed by the portable XRF of type Outokumpu X-Met; such data analysed in the field at the drill-site at Engebøfjellet are referred to as E $TiO_{2\ raw}$ while X-Met analyses done at NGUs core storage at Løkken are referred to as L $TiO_{2\ raw}$. In most cases one X-Met analysis were done pr. 0.25 m. The X-Met radiation window is approximately 3 cm^2 and each analysis is a quantitative number for that area only. Due to inhomogeneities in the rutile distribution within the rock the individual X-Met TiO_2-values scatter widely. The overall TiO_2-variation along the cores is shown by a trend-line calculated on the basis of the individual point-analyses, as illustrated in Fig. 8.

The X-Met data are semi quantitative, but the trend line gives excellent information about the overall titanium variations along the core and for distinguishing high-TiO_2 eclogite of potential ore-quality from eclogite that is not of ore quality.



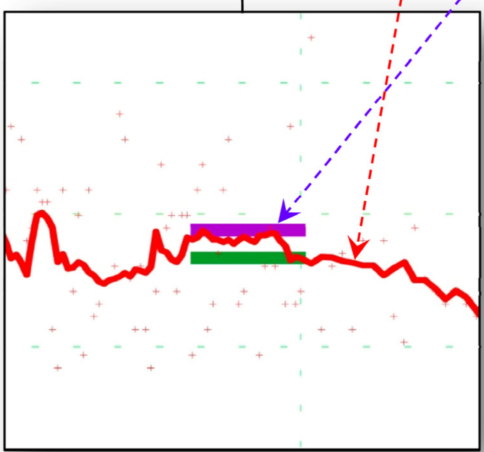


Fig. 8: Core analytical characteristics. For some 10m-sections such as 213/40-50 and 213/210-220 the 10m-section XRF-analyses (purple line) fit reasonably well with the X-Met trend line while others, such as 213/130-140 in this case, deviate significantly from the trend line. This demonstrates the semi-quantitative character of the method used. Another aspect is the effect of retrograde alteration which has not been adequately investigated quantitatively.

The XRF laboratory TiO_2 numbers were compared with the average number for the forty X-Met TiO_2 numbers from the same 10m core section (4 analyses/m x 10 m), and a correction factor determined based on one or several (if available) reference high-quality laboratory analyses for each core. Raw TiO_2 values from the same core were multiplied by the respective correction factors giving the $TiO_{2\ adj}$ number. For cores with more than one XRF reference analysis such as Bh213 in Fig. 8 (3 analyses), the correction number used for the core was the average of the individual correction numbers. For Dh 1, 2 and 3 this method of defining a correction factor was not followed. For cores without XRF reference analyses the original TiO_2 and Fe_2O_3 numbers were kept unadjusted (i.e. correction factor 1.0).

A simplified TiO_2 core analyses summary giving average values as well as the correction factors used is provided in Appendix 2. The complete data are available in an Access database and in Excel-file appendices to Korneliussen (1998).

Appendix 3 shows the variation in TiO_2 and magnetic susceptibility along all the 49 boreholes.

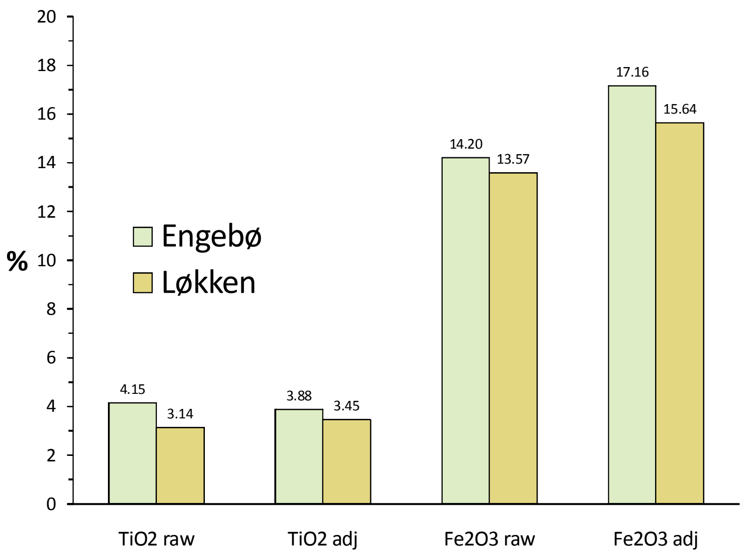


Fig. 9: Figure illustrating the difference between X-Met TiO_2 raw and adjusted data based on Table 1, as well as a Fe_2O_3-comparison. There is a distinct difference in TiO_2 raw vs. adjusted Løkken as well as TiO_2 raw vs. adj. Engebø, while the average of the Engebø and Løkken data show similar numbers (3.64 and 3.67 % TiO_2, respectively; see Table 1).

Table 2: Average X-Met TiO_2 and Fe_2O_3 raw and adjusted data based on Appendix 2.

	TiO_2 raw	TiO_2 adj.	TiO_2 adj.-raw	Fe_2O_3 raw	Fe_2O_3 adj.	Fe_2O_3 adj.-raw
Engebø	4.15	3.88	-0.26	14.20	17.16	2.96
Løkken	3.14	3.45	0.31	13.57	15.64	2.06
Average	3.64	3.67	0.03	13.89	16.40	2.51

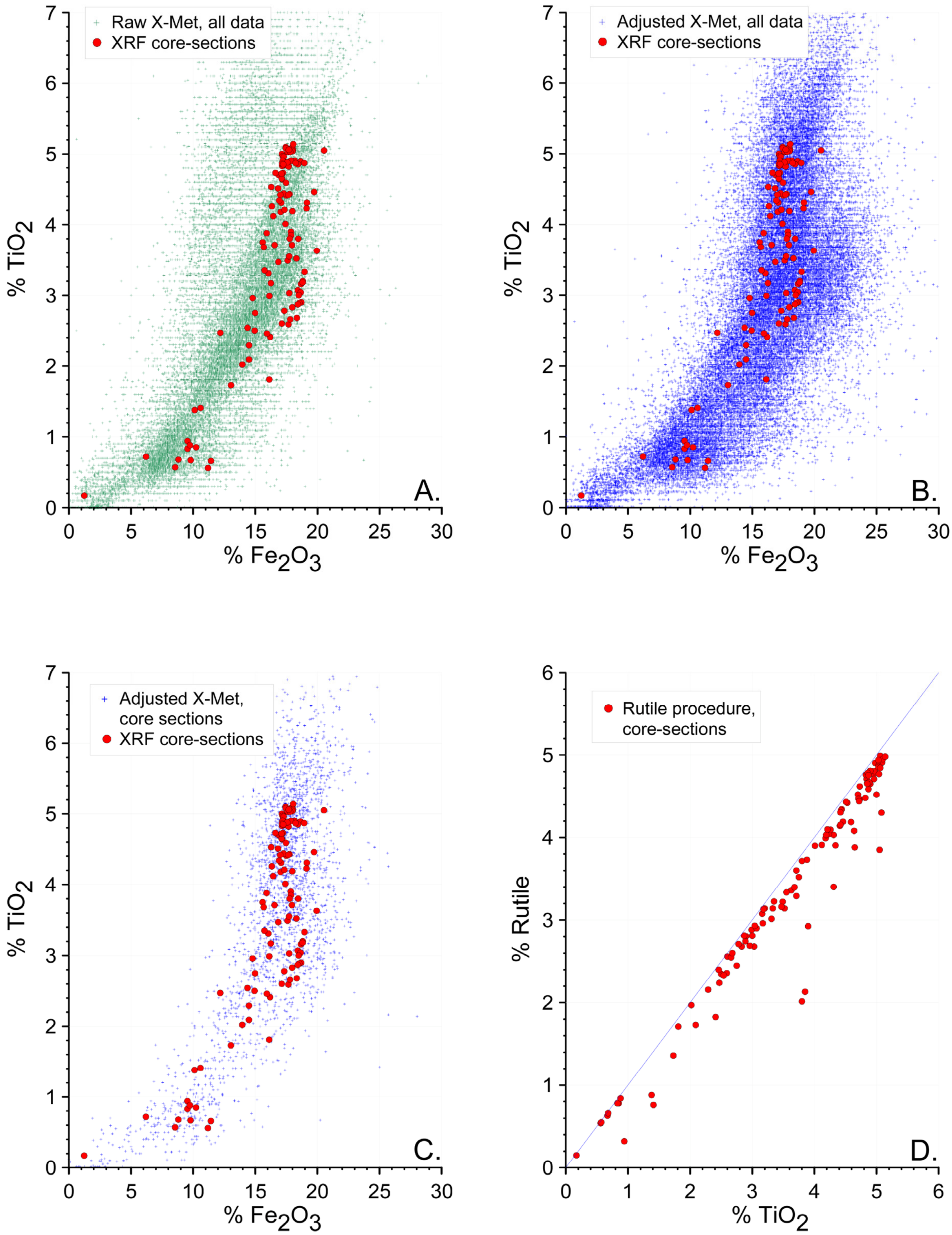


Fig. 10: Figures illustrating Fe_2O_3-TiO_2-rutile relationships. A: Fe_2O_3-TiO_2 relationships of the original X-Met analyses directly on cores carried out at the drill site at Engebøfjellet as well as within NGU's core store at Løkken, compared with laboratory analyses of core section samples (mainly 10m-sections, analyses by "rutile analytical procedure"). B: Fe_2O_3-TiO_2 plot of the adjusted X-Met data. C: Fe_2O_3-TiO_2 plot of the adjusted X-Met data for the same core sections that was analyzed in laboratory by the rutile analytical procedure. D: TiO_2-Rutile plot of the core sections analyzed by the rutile XRF+ICP procedure, based on data in Appendix 1.

In 1991, long before the DuPont-project, three rutile concentrates were made from representative samples from a drill-dust sample profile carried out in 1990 (Korneliussen and Furuhaug 1991). The three rutile concentrates were made by standard magnetic and heavy liquids mineral separation technique at NGU. Rutile separate labeled A (Table 2) is an impure concentrate, B is less impure while C was made "as pure as possible". These samples which were analysed by Titania AS by the "rutile procedure" contain 88.90, 92.71 and 94.73 % rutile, respectively. The purpose of this investigation was to find out if a rutile concentrate with ≤ 0.2 % CaO could be made; samples B and C fulfill these criteria well.

Table 2: Rutile-procedure analyses of rutile separates. Analysed by Titania 1991.

Sample	A	B	C
TiO_2	92.88	95.38	96.35
% P_2O_5	0.01	0.01	0.01
% S	0.20	0.26	0.30
% Cr_2O_3	0.01	0.02	0.03
% SiO_2	0.87	0.59	0.23
% V_2O_5	0.24	0.26	0.25
% CaO	0.20	0.10	0.03
% MgO	0.11	0.02	0.00
% Al_2O_3	0.80	0.57	0.45
% Fe_2O_3	4.66	2.25	1.67
% Sum	*99.98*	*99.45*	*99.32*
TiO_2 (HCl)	3.98	2.67	1.62
% Rutile	88.90	92.71	94.73

In 2006 a selection of rutile and ilmenite samples from various Ti and Fe-Ti deposits including the above sample C from Engebøfjellet, were analyzed by laser-ablation ICP-MS at NGU (Korneliussen and Skår, in prep.). Four raster analyses (c. 50 x 50 microns) were done on rutile within sample C (Table 3). Analyses number C_068 is distinctly enriched in Fe and Mg compared with the other three analyses, indicating that the laser has hit an ilmenite inclusion in the rutile. These analyses show that Engebøfjellet rutile has a generally high titanium content (> 98 % TiO_2), low iron content (c. 0.3-0.5 % FeO), relatively high vanadium content (1000-1600 ppm V) and very low contents of the radioactive elements thorium and uranium.

Table 3: Laser-ablation analyses of rutile. Analysed by NGU 2006 (not previously reported).

Anal. no		C_067	C_068	C_069	C_070
TiO_2	%	98.50	94.30	98.60	98.90
Fe	ppm	2915	39127	3590	2352
FeO	%	0.37	5.03	0.46	0.30
Mg	ppm	0.00	451.60	0.00	0.00
Al	ppm	0.00	0.00	0.00	0.00
Si	ppm	< 79.3	85.6	86.3	387.2
Ca	ppm	< 49.9	49.9	133.4	< 51.7
Sc	ppm	1.23	1.90	0.97	1.56
V	ppm	1582	1347	1160	1064
Cr	ppm	36.5	154.4	243.6	28.0
Mn	ppm	< 1.06	183.87	< 1.07	< 1.2
Co	ppm	< 0.27	19.85	< 0.27	< 0.35
Ni	ppm	< 2.05	16.35	< 2.21	< 2.52
Zn	ppm	2.59	15.08	2.71	< 1.23
As	ppm	< 1	< 1	< 1	< 1
Y	ppm	< 0.06	< 0.05	< 0.07	0.09
Zr	ppm	374	419	407	336
Nb	ppm	94.5	76.1	79.2	86.1
Cd	ppm	< 1	< 1	< 1	< 1
Sb	ppm	0.13	0.18	< 0.20	0.18
La	ppm	< 0.02	< 0.04	0.05	< 0.02
Hf	ppm	11.4	11.7	10.4	8.7
Ta	ppm	7.86	4.57	4.58	2.72
W	ppm	0.37	4.37	0.60	0.82
Th	ppm	< 0.01	< 0.01	< 0.02	< 0.02
U	ppm	0.20	0.60	0.25	0.40

5. DISCUSSION

GENERAL

Engebøfjellet is a pioneering project since it must meet rutile concentrate quality requirements as if it was a sand deposit (see Korneliussen et al. 2000 for further information). Large-scale hard-rock rutile mining is not being done anywhere in the world, and the main reason is probably "liberation" as further discussed below.

Rutile is feed for TiO_2-pigment production by the chloride process. There is a whole range of quality requirements. In the DuPont-project the grain-size requirement was that 90 % of the rutile in the concentrate should be larger than 45 microns, and the calcium content should be less than 0.2 % CaO (preferentially less than 0.1 %) equivalent to approximately 2 % (1 %) of silicate minerals.

Rutile is a hard, brittle mineral interstitial to garnet which is another hard, brittle mineral; milling easily smashes rutile to small grains and dust-like particles making it difficult to achieve a rutile concentrate of sufficient grain-size quality. A main issue in the DuPont-project (not further discussed in this report) was to optimise the milling procedure to liberate rutile grains without pulverising it to dust.

Calcium is a major constituent in all the major eclogite silicate minerals (the CaO contents in garnet, amphibole and omphacite are roughly 12%, 9 % and 8 %, respectively; see electron microprobe analyses in Korneliussen et al. (1998). To fulfil the CaO requirement with good enough rutile recovery, good liberation of rutile from the silicate minerals is a necessity, followed by an effective enrichment of rutile into a concentrate almost free of calcium-bearing silicate minerals.

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 is also shown that iron-rich eclogites are usually also garnet-rich, since much of the iron in the rock enters garnet which is 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). 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 low iron and titanium content (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.

CORE ANALYSES

The analyses carried out on cores by X-Met portable XRF during the DuPont project, are semi-quantitative. These analyses, particularly the TiO_2 trend-line (Fig. 8), define the overall TiO_2-distribution along the cores. Combined with reference samples (usually 10m-sections) analysed by laboratory XRF, adjusted X-Met data give fairly reliable information on the large-scale TiO_2

distribution along the cores, but are not reliable on a meter scale and are only indicative on a 10m scale. This is illustrated by the various Dh-figures in Appendix 3, in which most of the XRF reference analyses (if available) plot well in line with the TiO_2 trend-line while others do not.

Retrograde alteration of eclogite tends to alter rutile to ilmenite. In general the rutile/TiO_2-ratio is 0.9 or higher (Fig. 6 and Appendix 1), roughly indicating that more than 90% of the titanium in the rock occurs as rutile. Although titanium in silicate minerals (on average approximately 0.1 % TiO_2) has been neglected, the overall statement that at least 90% of the titanium in the rock occurs as rutile seems to be valid.

Mineral processing is not the subject of this report, but it is strongly recommended that the effect of retrograde alteration in relation to mineral processing is carefully studied.

Fresh eclogite does not contain magnetite and is a low-magnetic rock. Dust-like particles of secondary magnetite have formed during retrograde alteration, and retrograded eclogite tends to be distinctly magnetic. Thus, by measuring magnetic susceptibility it will be possible to map retrograde alteration zones within the deposit. Such mapping is recommended since retrograde alteration changes the overall character of the rock as well as altering rutile to ilmenite and occasionally also to titanite. Since retrograde alteration changes the rock's character it probably also affects its behaviour in mineral processing.

Ore-grade control combined with mineralogical control is crucial, as also pointed out in the garnet report (Korneliussen et al. 2008).

For prioritised parts of the deposit, i.e. those parts that are planned to be mined, further analytical work on cores is recommended as follows:

- 5m-sections with average X-Met $TiO_{2\ adj.}$ above 2.5 % TiO_2 should be reanalysed by the rutile procedure (XRF and ICP), to give precise data on TiO_2 and rutile content.
- It is also advised to carry out SEM-characterisation of polished sections of representative core samples focusing on rutile (/ilmenite) and garnet grain characteristics, based on image processing of mosaic bse (back-scattered electron) images.

STRUCTURAL 3D-CONTROL

The deposit is highly affected by deformation episodes as described by Korneliussen et al. (1998; see Appendix 3 written by Alvar Braathen). Rutile ore is folded by eclogite-facies folding, which to some extent control the distribution of titanium-rich versus titanium-poor eclogite rock. It is probable that this deformation that occurred during the eclogite-forming process, also affected the rutile and garnet grain-size, and is therefore indirectly affecting the mineral processing characteristics and the quality of the final mineral concentrates. Good understanding and 3D-control of eclogite-facies deformation is therefore advisable.

A 3D-model is necessary to control the overall TiO_2 ore-pattern, and sufficiently dense drilling is required to achieve a good-enough ore control. Understanding of the eclogite-facies deformation events might help in building up a good 3D ore model.

Deformation under retrograde conditions (amphibolite and greenshist facies) causes rutile to alter to ilmenite in addition to altering silicate minerals and changing the overall character of the rock. It is probable that this alteration affects the mineral processing characteristics of the ore. It is therefore also for this reason recommended that a structural 3D-control of the deposit be established.

6. CONCLUSION

The importance of having excellent TiO_2- and rutile 3D grade control is obvious for ore reserve and mine planning reasons, and the way to achieve this is to drill "densely enough" combined with relevant analytical work. In addition, due to the mineralogical complexity of the rock, it is advisable to integrate information of mineralogical characteristics that might affect mineral processing.

Evaluation of the core analytical data from the DuPont-project confirms that the core analyses carried out by X-Met portable XRF are fairly good but semi-quantitative. In general, adjusted X-Met data give an overall correct picture of the TiO_2-distribution along cores and provide reliable average TiO_2 content for large core sections, but are not reliable at meter-scale and only indicative at 10-meter scale.

Retrograde alteration of eclogite tends to alter rutile to ilmenite. In general the rutile/TiO_2-ratio is ≥0.9, roughly indicating that more than 90% off the titanium in the rock occurs as rutile. Although titanium in silicate minerals (in average c. 0.1 % TiO_2) has been neglected, the overall statement that at least 90% of the titanium in the rock occurs as rutile seems to be valid.

For prioritised parts of the deposit, i.e. those parts that are planned to be mined, rutile-procedure analyses of potential rutile ore eclogite in 5m-sections are recommended.

It is also advised in order to achieve mineralogical control, to SEM-analyse polished sections of representative core samples systematically focusing on rutile (/ilmenite) and garnet grain characteristics, based on image processing of mosaic SEM-images.

7. REFERENCES

Only reports referred to is listed; in addition a large amount of reports from the DuPont-project (1995-97) is available.

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

Korneliussen, A. 1998: Information compilation Engebøfjellet 1997. Project-internal report from NGU to DuPont/Conoco, February 1998. 27 p. + 10 appendixes (8 cm thick pile of paper printouts most of which is available in digital form).

Korneliussen, A., Braathen, A., Erambert, M., Lutro, O., Ragnhildstveit, J., 1998: The geology of the Engebøfjell eclogite deposit and its regional setting. NGU report 98.081, 118 p.

Korneliussen, A., Furuhaug, L., 1991: Fureviknipa og Engebøfjellet rutilforekomster ved Førdefjorden, Sogn og Fjordane. NGU-rapport 91.171.

Korneliussen, A., Gautneb, H. & Raaness, A. 2008: Characterisation of garnet, Engebøfjellet rutile deposit. NGU report 2008.082, 30 p. + appendix.

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.

Appendix 1:

Table 1A: 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 1B: 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	

Appendix 2: Engebøfjellet core analyses summary, DuPont-project (1995-97)

COMMENTS

X-Met: Portable XRF instrument of type Outokumpu X-Met.
X-Met Løkken: Field analyses carried out directly on drillcore at NGUs core store at Løkken.
X-Met Engebøfjellet: Field analyses carried out directly on drillcore at the drill-site at Engebøfjellet.
TiO2 raw: The original X-Met TiO2 numbers
TiO2 adj.: Adjusted X-Met TiO2 data based on a correction factor (see explanation in the main text).

Rutile analytical procedure (NGU lab.): Analytical method combining XRF (total) and ICP (acid soluble).
% Rutile = TiO2 total (XRF) - TiO2 acid soluble (ICP); see main text for further explanation.

Mag susc: Magnetic susceptibility times 100000.

	X-Met Løkken		X-Met Engebøfjellet		Rutile analytical procedure (NGU lab.)					
Sample	%TiO2 raw	%TiO2 adj	%TiO2 raw	%TiO2 adj	%TiO2 xrf	%Fe2O3 xrf	%TiO2 icp	%Rutile calc.	%Rut./ %TiO2	Mag. susc.
Avg. 1/101-103	4.06	4.06			3.49	17.60	0.16	3.22	0.92	2.6
Avg. 1/126-127	3.53	3.53			3.71	17.95	0.25	3.29	0.89	5.1
Avg. 1/160-170	0.74	0.74			1.41	10.59	0.39	0.76	0.54	2.2
Avg. 1/176-179	0.47	0.47			0.72	6.20				2.0
Avg. 1/20-30	0.70	0.70			0.94	9.54	0.37	0.32	0.34	2.2
Avg. 1/65-66	1.23	1.23			1.81	16.12	0.06	1.71	0.94	1.5
Avg. Dh 1	1.13	1.13			1.41	10.71	0.34	0.93	0.52	2.3
Drillhole adjustment factor:		1.00								
Avg. 2/115-116	3.82	4.47			4.90	18.17	0.15	4.65	0.95	1.0
Avg. 2/150-155	3.13	3.66			3.63	19.94	0.16	3.36	0.93	3.0
Avg. 2/165-170	4.30	5.03			5.05	18.02	0.09	4.90	0.97	2.8
Avg. 2/200-205	3.05	3.56			3.52	18.31	0.23	3.14	0.89	8.5
Avg. 2/260-270	0.97	1.14			1.38	10.11	0.30	0.88	0.64	2.5
Avg. 2/95-105	1.17	1.37			1.73	13.04	0.22	1.36	0.79	2.0
Avg. Dh 2	2.17	2.54			2.72	14.81	0.21	2.36	0.81	3.3
Drillhole adjustment factor:		1.17								
Avg. 3/110-111	0.48	0.53			0.85	10.23	0.04	0.78	0.92	0.2
Avg. 3/135-136	1.63	1.80			2.02	13.95	0.03	1.97	0.98	0.9
Avg. 3/15-20	0.61	0.67			0.88	9.74	0.03	0.84	0.95	0.2
Avg. 3/159-160	4.58	5.08			5.08	17.89	0.06	4.97	0.98	0.8
Avg. 3/60-65	0.45	0.50			0.83	9.54	0.03	0.78	0.94	0.3
Avg. 3/80-85	0.00	0.00			0.17	1.23	0.01	0.15	0.88	0.1
Avg. Dh 3	0.66	0.74			0.96	8.03	0.03	0.92	0.93	0.3
Drillhole adjustment factor:		1.11								
Avg. 4/106-108	3.18	3.33			2.99	16.13	0.07	2.88	0.96	0.9
Avg. 4/120-121	5.15	5.41			5.05	20.53	0.72	3.85	0.76	4.3
Avg. 4/130-131	4.58	4.80			4.46	19.73	0.16	4.19	0.94	1.3
Avg. 4/151-152	4.35	4.57			4.41	17.49	0.16	4.14	0.94	2.9
Avg. 4/36-40	1.50	1.58			2.59	17.67	0.14	2.36	0.91	5.2
Avg. 4/75-77	5.28	5.54			5.09	17.98	0.11	4.91	0.96	1.0
Avg. 4/97-98	5.78	6.06			4.44	17.28	0.06	4.34	0.98	0.8
Avg. Dh 4	3.56	3.74			3.74	17.83	0.17	3.46	0.93	2.5
Drillhole adjustment factor:		1.05								
Avg. 9/(350-355)	0.82	0.79			0.66	11.43				6.7
Avg. Dh 9	0.82	0.79			0.66	11.43				6.7
Drillhole adjustment factor:		0.96								

Sample	X-Met Løkken %TiO2 raw	X-Met Løkken %TiO2 adj	X-Met Engebøfjellet %TiO2 raw	X-Met Engebøfjellet %TiO2 adj	Rutile analytical procedure (NGU lab.) %TiO2 xrf	%Fe2O3 xrf	%TiO2 icp	%Rutile calc.	%Rut./ %TiO2	Mag. susc.
Avg. 10/120-125	3.02	2.89			2.60	17.13		2.56	0.98	0.5
Avg. 10/145-150	4.99	4.79			4.89	18.64		4.77	0.98	0.6
Avg. 10/240-245	5.19	4.98			4.84	17.39		4.71	0.97	0.4
Avg. 10/290-295	4.57	4.39			4.70	16.88		4.52	0.96	0.0
Avg. Dh 10	4.44	4.26			4.26	17.51		4.14	0.97	0.4
Drillhole adjustment factor:		0.96								
Avg. 11/140-150	2.50	2.88			2.90	18.70	0.10	2.80	0.97	0.7
Avg. 11/200-210	4.22	4.85			4.83	17.16	0.07	4.76	0.99	0.4
Avg. Dh 11	3.35	3.85			3.87	17.93	0.08	3.78	0.98	0.5
Drillhole adjustment factor:		1.15								
Avg. 12/270-280	4.18	4.89			4.98	17.26	0.08	4.91	0.98	1.0
Avg. 12/370-380	4.15	4.86			4.73	17.22	0.11	4.62	0.98	
Avg. Dh 12	4.17	4.87			4.86	17.24	0.09	4.76	0.98	1.0
Drillhole adjustment factor:		1.17								
Avg. 13/100-105	5.32	4.95			4.85	18.43	0.19	4.66	0.96	0.8
Avg. 13/130-140	5.59	5.20			5.06	18.02	0.07	4.99	0.99	1.5
Avg. 13/150-160	5.15	4.79			4.90	17.87	0.09	4.81	0.98	1.6
Avg. 13/180-181	4.63	4.31			4.73	16.62	0.27	4.46	0.94	3.0
Avg. 13/182-183	4.76	4.43			5.10	17.44	0.15	4.95	0.97	4.5
Avg. 13/190-200	4.89	4.55			4.88	17.30	0.21	4.67	0.96	8.3
Avg. 13/230-240	3.75	3.49			3.07	18.42	0.17	2.90	0.94	2.3
Avg. 13/257-258	3.55	3.30			3.16	18.68	0.09	3.08	0.97	2.2
Avg. 13/259.1-26	2.65	2.47			2.47	12.18	0.23	2.24	0.91	
Avg. Dh 13	4.83	4.49			4.48	17.85	0.14	4.33	0.97	3.1
Drillhole adjustment factor:		0.93								
Avg. 102/10-20	3.00	3.18	3.83	3.21	3.47	16.85		3.16	0.91	2.0
Avg. 102/120-130	2.84	3.01	3.36	2.82	2.83	17.97		2.68	0.95	0.7
Avg. 102/180-190	4.63	4.91	6.21	5.21	4.71	17.13		4.47	0.95	0.8
Avg. 102/250-260	4.33	4.59	5.31	4.46	4.64	17.16		4.08	0.88	2.8
Avg. Dh 102	3.70	3.93	4.68	3.94	3.92	17.28		3.60	0.92	1.8
Drillhole adjustment factor:		1.06		0.84						
Avg. 103/110-120	3.43	3.84	3.62	3.33	3.33	18.96		3.14	0.94	0.8
Avg. 103/220-230	2.98	3.34	3.36	3.09	2.78	17.33		2.71	0.97	0.7
Avg. 103/360-370			4.71	4.33	4.65	17.12		3.88	0.83	7.6
Avg. 103/50-60	0.73	0.82	0.88	0.81	0.67	9.79		0.63	0.94	0.2
Avg. Dh 103	2.38	2.66	3.46	3.19	2.86	15.80		2.59	0.92	3.4
Drillhole adjustment factor:		1.12		0.92						
Avg. 104/200-210			3.00	2.64	2.66	17.80		2.55	0.96	0.9
Avg. 104/330-340			5.10	4.48	4.31	19.15		4.03	0.94	1.1
Avg. 104/90-100			4.93	4.34	4.43	17.75		4.33	0.98	0.7
Avg. Dh 104			4.34	3.82	3.80	18.23		3.64	0.96	0.9
Drillhole adjustment factor:				0.88						
Avg. 107/190-200			3.16	3.03	3.04	18.65		2.93	0.96	0.6
Avg. 107/50-60	0.65		0.80	0.77	0.56	11.19		0.54	0.96	0.3
Avg. Dh 107	0.65		2.37	2.28	1.80	14.92		1.74	0.96	0.4
Drillhole adjustment factor:				0.96						
Avg. 108/130-140			4.26	3.75	4.23	19.12		4.04	0.96	0.9
Avg. 108/200-210			3.47	3.05	3.03	17.73		2.68	0.88	0.8
Avg. 108/340-350			6.33	5.57	5.08	17.45		4.30	0.85	1.4
Avg. 108/50-60			0.99	0.87	0.57	8.55		0.55	0.96	0.2
Avg. Dh 108			4.16	3.66	3.23	15.71		2.89	0.91	0.8
Drillhole adjustment factor:				0.88						
Avg. 109/140-150			4.18	3.89	3.88	15.91		3.73	0.96	1.2
Avg. 109/200-210			5.38	5.00	5.03	17.65		4.87	0.97	0.9
Avg. Dh 109			4.78	4.45	4.45	16.78		4.30	0.96	1.0
Drillhole adjustment factor:				0.93						
Avg. 110/110-120			2.30	2.04	2.09	14.49		1.73	0.83	4.9
Avg. 110/170-180			5.98	5.32	4.95	17.26		4.77	0.96	8.0
Avg. 110/290-300			5.16	4.59	5.00	17.14		4.52	0.90	1.8
Avg. Dh 110			4.48	3.98	4.01	16.30		3.67	0.90	5.2
Drillhole adjustment factor:				0.89						

Sample	X-Met Løkken %TiO2 raw	X-Met Løkken %TiO2 adj	X-Met Engebøfjellet %TiO2 raw	X-Met Engebøfjellet %TiO2 adj	Rutile analytical procedure (NGU lab.) %TiO2 xrf	%Fe2O3 xrf	%TiO2 icp	%Rutile calc.	%Rut./ %TiO2	Mag. susc.
Avg. 111/200-210			4.66	4.84	4.59	17.47	0.40	4.19	0.91	1.5
Avg. 111/330-340			3.89	4.05	4.26	16.33	0.17	4.09	0.96	0.6
Avg. 111/60-70			0.84	0.87	0.68	8.81	0.02	0.66	0.97	0.2
Avg. Dh 111			3.59	3.73	3.18	14.20	0.20	2.98	0.95	0.8
Drillhole adjustment factor:				1.04						
Avg. 112/180-190	4.05	4.98	4.68	4.63	4.97	17.20	0.16	4.81	0.97	0.3
Avg. 112/260-270	2.00	2.46	3.05	3.02	2.41	16.19	0.58	1.83	0.76	0.7
Avg. 112/360-370	3.58	4.40	4.80	4.75	4.42	17.01	0.27	4.15	0.94	1.5
Avg. Dh 112	3.21	3.95	4.18	4.13	3.93	16.80	0.34	3.60	0.89	0.8
Drillhole adjustment factor:		1.23		0.99						
Avg. 113/170-180			3.92	3.72	3.90	17.86	0.98	2.92	0.75	2.3
Avg. 113/240-250			3.12	2.96	3.00	18.49	0.19	2.81	0.94	
Avg. Dh 113			3.65	3.47	3.45	18.18	0.58	2.87	0.84	2.3
Drillhole adjustment factor:				0.95						
Avg. 114/100-110			3.74	3.85	3.85	17.87	1.72	2.13	0.55	6.7
Avg. Dh 114			3.74	3.85	3.85	17.87	1.72	2.13	0.55	6.7
Drillhole adjustment factor:				1.03						
Avg. 202/180-190			3.75	3.23	2.96	14.78		2.69	0.91	3.3
Avg. 202/20-30			4.38	3.77	3.71	16.55		3.60	0.97	0.7
Avg. 202/70-80			4.33	3.72	4.01	17.42		3.90	0.97	1.0
Avg. Dh 202			4.15	3.57	3.56	16.25		3.40	0.95	1.9
Drillhole adjustment factor:				0.86						
Avg. 203/170-180			2.92	2.83	2.75	14.98		2.45	0.89	2.7
Avg. 203/20-30			4.21	4.08	4.18	17.04		3.99	0.95	1.0
Avg. Dh 203			3.58	3.47	3.47	16.01		3.22	0.92	2.1
Drillhole adjustment factor:				0.97						
Avg. 204/10-20			4.48	4.21	4.19	17.98		4.03	0.96	1.1
Avg. 204/130-140			3.96	3.72	3.75	15.59		3.52	0.94	3.0
Avg. Dh 204			4.22	3.96	3.97	16.79		3.78	0.95	2.2
Drillhole adjustment factor:				0.94						
Avg. 207/110-120			5.95	5.06	5.04	17.99		4.77	0.95	1.0
Avg. 207/130-140			5.69	4.83	4.96	17.29		4.71	0.95	0.8
Avg. 207/60-70			3.84	3.26	3.20	18.82		3.14	0.98	0.6
Avg. Dh 207			5.16	4.38	4.40	18.03		4.21	0.96	0.8
Drillhole adjustment factor:				0.85						
Avg. 208/130-140			5.24	4.30	4.53	16.28		4.42	0.98	0.8
Avg. 208/270-280			6.07	4.97	4.72	17.11		4.44	0.94	1.3
Avg. 208/50-60			2.65	2.17	2.50	14.94		2.35	0.94	0.5
Avg. Dh 208			4.65	3.81	3.92	16.11		3.74	0.95	0.9
Drillhole adjustment factor:				0.82						
Avg. 209/150-160			5.88	5.29	5.03	17.61		4.94	0.98	0.6
Avg. 209/90-100			3.81	3.43	3.18	18.81		3.13	0.98	0.6
Avg. Dh 209			4.85	4.36	4.11	18.21		4.04	0.98	0.6
Drillhole adjustment factor:				0.90						
Avg. 210/100-110	2.16	2.41	2.93	2.69	2.46	15.93		2.40	0.98	0.6
Avg. 210/240-250	4.26	4.77	4.99	4.59	4.82	17.68		4.48	0.93	2.0
Avg. 210/340-350	2.86	3.20	3.70	3.40	3.17	16.25		2.96	0.93	5.0
Avg. Dh 210	3.09	3.46	3.87	3.56	3.48	16.62		3.28	0.95	2.8
Drillhole adjustment factor:		1.12		0.92						
Avg. 211/130-140			3.48	3.61	3.80	17.77	1.78	2.02	0.53	4.7
Avg. 211/210-220			3.67	3.82	4.34	16.92	0.44	3.90	0.90	5.7
Avg. 211/310-320			5.25	5.46	5.03	17.80	0.18	4.85	0.96	0.7
Avg. 211/410-420			4.41	4.59	4.31	17.08	0.91	3.40	0.79	1.2
Avg. Dh 211			4.20	4.37	4.37	17.39	0.83	3.54	0.80	3.1
Drillhole adjustment factor:				1.04						
Avg. 212/170-180	3.74	4.30	3.92	4.19	4.12	16.44	0.21	3.91	0.95	0.7
Avg. 212/270-280	3.22	3.71	3.42	3.65	3.68	15.68	0.28	3.40	0.92	0.9
Avg. 212/70-80	4.11	4.72	4.58	4.90	4.90	17.20	0.09	4.81	0.98	0.3
Avg. Dh 212	3.69	4.24	3.97	4.25	4.23	16.44	0.20	4.04	0.95	0.6
Drillhole adjustment factor:		1.15		1.07						

Sample	X-Met Løkken %TiO2 raw	X-Met Løkken %TiO2 adj	X-Met Engebøfjellet %TiO2 raw	X-Met Engebøfjellet %TiO2 adj	Rutile analytical procedure (NGU lab.) %TiO2 xrf	%Fe2O3 xrf	%TiO2 icp	%Rutile calc.	%Rut./ %TiO2	Mag. susc.
Avg. 213/130-140			2.25	2.16	2.29	14.49	0.13	2.16	0.94	1.8
Avg. 213/210-220			3.22	3.09	3.31	16.05	0.30	3.01	0.91	2.2
Avg. 213/40-50			5.03	4.83	4.88	17.57	0.21	4.67	0.96	1.4
Avg. Dh 213			3.80	3.64	3.49	16.04	0.21	3.28	0.94	1.8
Drillhole adjustment factor:				0.96						
Avg. 214/200-210			5.08	5.33	4.87	18.94	0.28	4.59	0.94	1.7
Avg. 214/310-320			3.08	3.23	2.54	14.37	0.21	2.33	0.92	1.9
Avg. 214/40-50			3.56	3.73	4.86	17.15	0.08	4.78	0.98	0.4
Avg. Dh 214			3.90	4.10	4.09	16.82	0.19	3.90	0.95	1.4
Drillhole adjustment factor:				1.05						
Avg. 301/100-110			2.67	2.64	2.68	18.34	0.08	2.60	0.97	0.5
Avg. 301/190-200			4.22	4.18	4.21	17.34	0.11	4.10	0.97	0.7
Avg. 301/40-50			5.01	4.96	4.87	18.24	0.11	4.76	0.98	0.6
Avg. Dh 301			3.97	3.93	3.92	17.97	0.10	3.82	0.97	0.6
Drillhole adjustment factor:				0.99						
Avg. 302/190-200			4.08	4.20	5.06	17.69	0.22	4.84	0.96	1.6
Avg. 302/30-40			4.71	4.85	4.51	16.83	0.08	4.43	0.98	0.4
Avg. 302/330-340			5.47	5.63	5.14	18.05	0.16	4.98	0.97	0.5
Avg. Dh 302			4.75	4.89	4.90	17.52	0.15	4.75	0.97	0.8
Drillhole adjustment factor:				1.03						
Avg. 303/140-150			5.00	4.60	4.42	17.66	0.12	4.30	0.97	0.4
Avg. 303/230-240			3.67	3.38	3.35	15.74	0.13	3.22	0.96	0.4
Avg. 303/40-50			4.10	3.77	3.80	18.45	0.09	3.71	0.98	0.3
Avg. 303/90-100			2.93	2.69	2.89	18.54	0.15	2.74	0.95	0.5
Avg. Dh 303			3.92	3.61	3.62	17.60	0.12	3.50	0.97	0.4
Drillhole adjustment factor:				0.92						
Avg. 304/200-210			5.01	4.60	4.85	17.24	0.20	4.65	0.96	0.7
Avg. 304/330-340			4.03	3.70	3.55	17.72	0.22	3.33	0.94	1.8
Avg. 304/80-90			3.21	2.95	2.87	18.42	0.06	2.81	0.98	0.7
Avg. Dh 304			4.08	3.75	3.76	17.79	0.16	3.60	0.96	1.1
Drillhole adjustment factor:				0.92						
Avg. all data:	3.14	3.45	4.15	3.88	3.67	16.49	0.27	3.43	0.92	2.0
ALL DATA avg. adjustm. factor:		1.10		0.94						

Appendix 3:

TiO_2 and magnetic susceptibility variations along boreholes

Engebøfjellet core information
DuPont-NGU project 1995-97

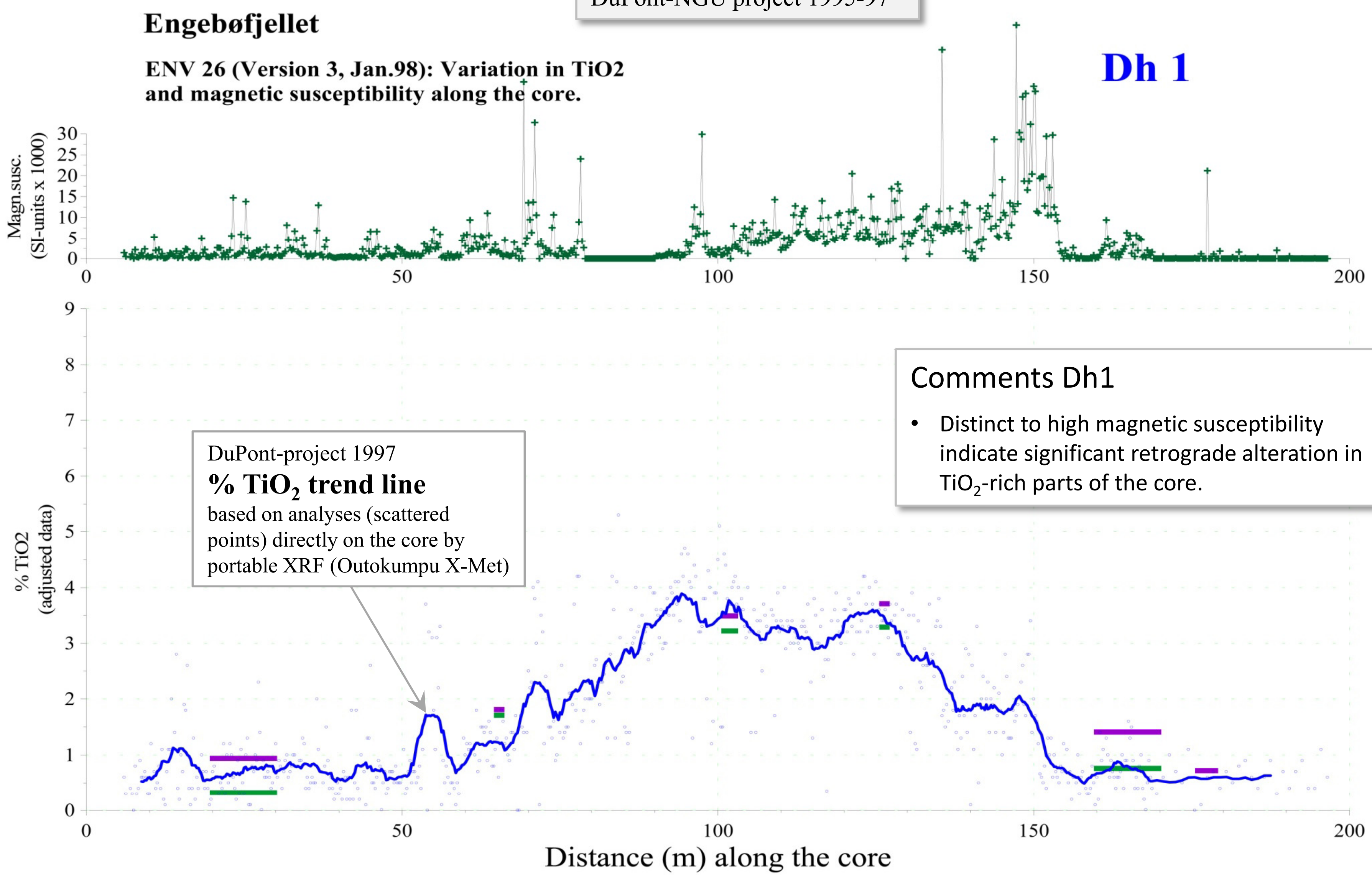
49 boreholes:

- Dh1-17 (17 boreholes)
- Dh101-114 (14 boreholes)
- Dh201-214 (14 boreholes)
- Dh301-304 (4 boreholes)

Engebøfjellet core information

Borehole 1

DuPont-NGU project 1995-97



Comments Dh1

- Distinct to high magnetic susceptibility indicate significant retrograde alteration in TiO_2-rich parts of the core.

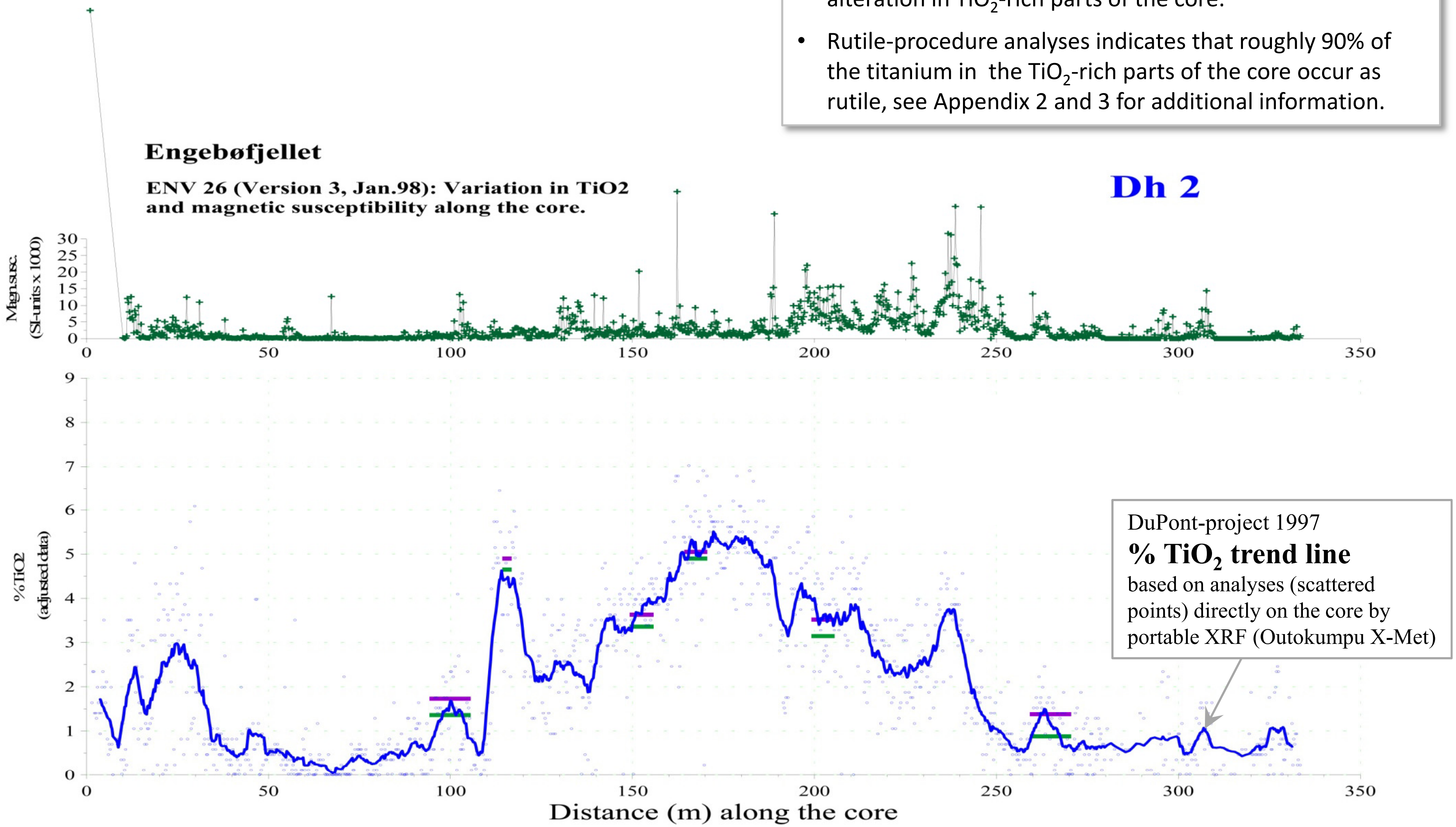
Engebøfjellet core information

Borehole 2

DuPont-NGU project 1995-97

Comments Dh2

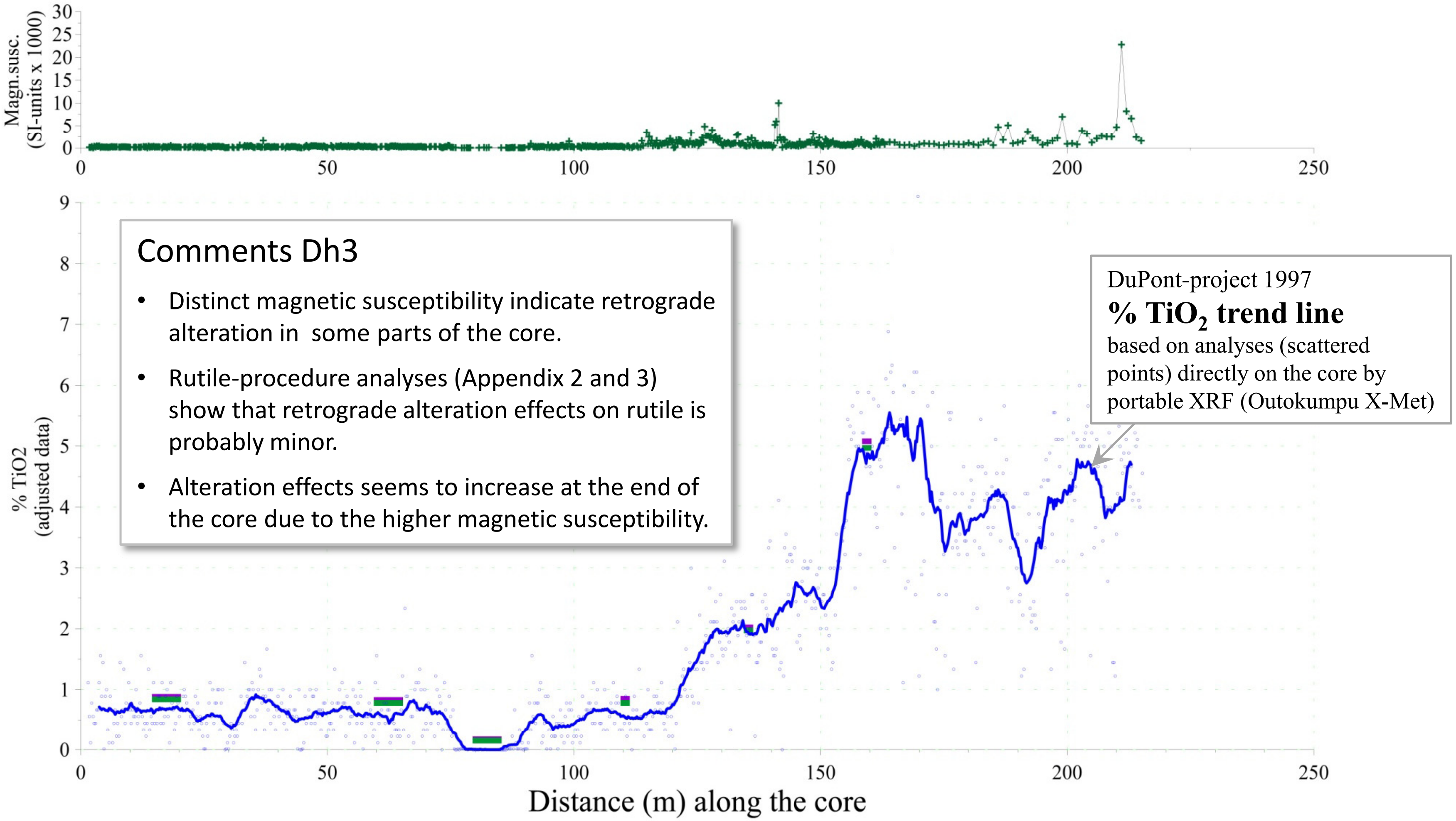
- Distinct to high magnetic susceptibility indicate retrograde alteration in TiO_2-rich parts of the core.
- Rutile-procedure analyses indicates that roughly 90% of the titanium in the TiO_2-rich parts of the core occur as rutile, see Appendix 2 and 3 for additional information.



Engebøfjellet core information
Borehole 3
DuPont-NGU project 1995-97

Engebøfjellet

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



Comments Dh3

- Distinct magnetic susceptibility indicate retrograde alteration in some parts of the core.
- Rutile-procedure analyses (Appendix 2 and 3) show that retrograde alteration effects on rutile is probably minor.
- Alteration effects seems to increase at the end of the core due to the higher magnetic susceptibility.

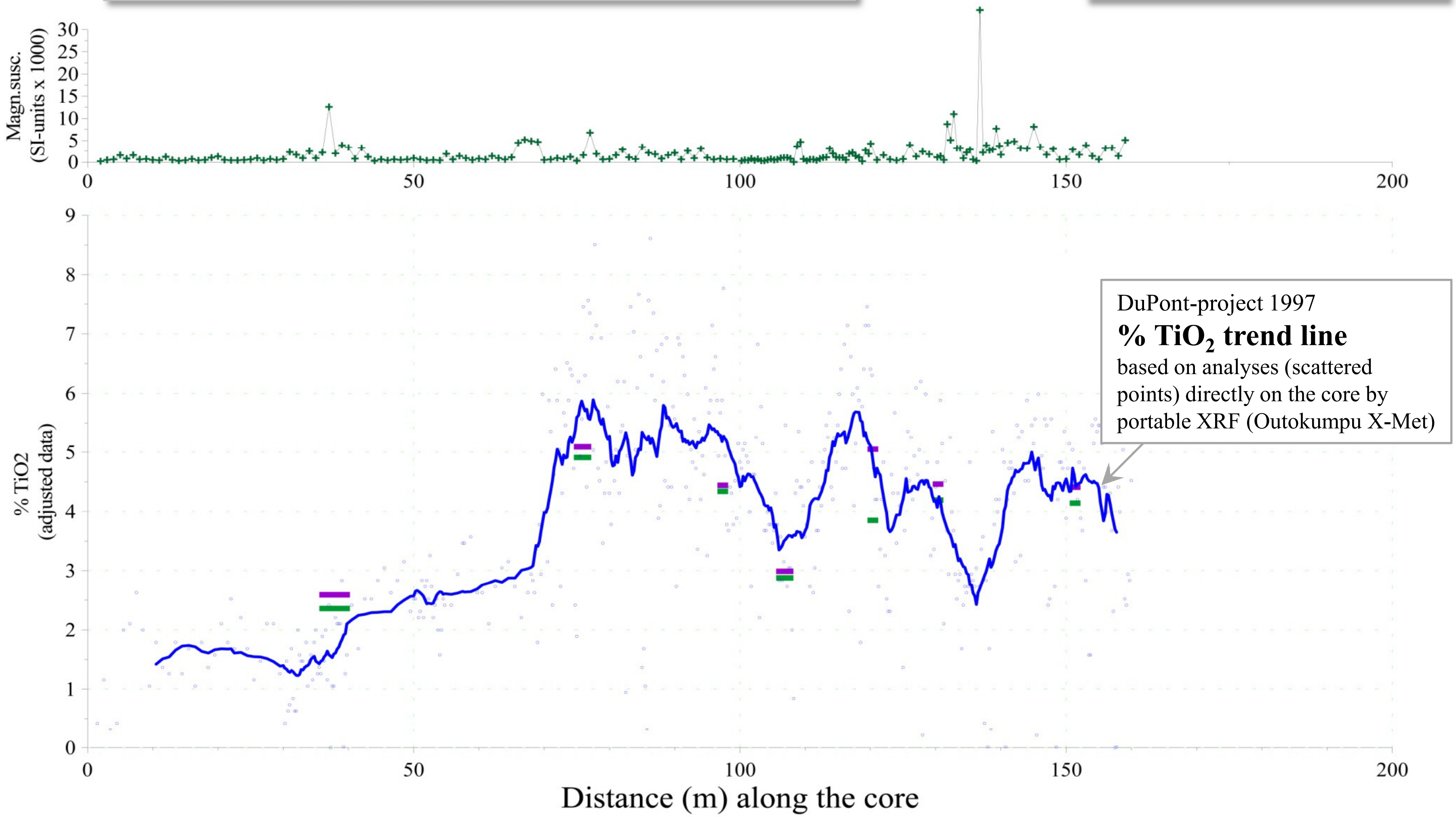
Comments Dh4

- Variable, but generally low to moderate magnetic susceptibility, indicating overall minor retrograde effects on rutile.
- However, sample 4/120-121 (see Appendix 2 and 3) is considerably altered with rutile/TiO_2= 0.75, with only weak to moderate magnetic susceptibility.

Engebøfjellet core information

Borehole 4

DuPont-NGU project 1995-97



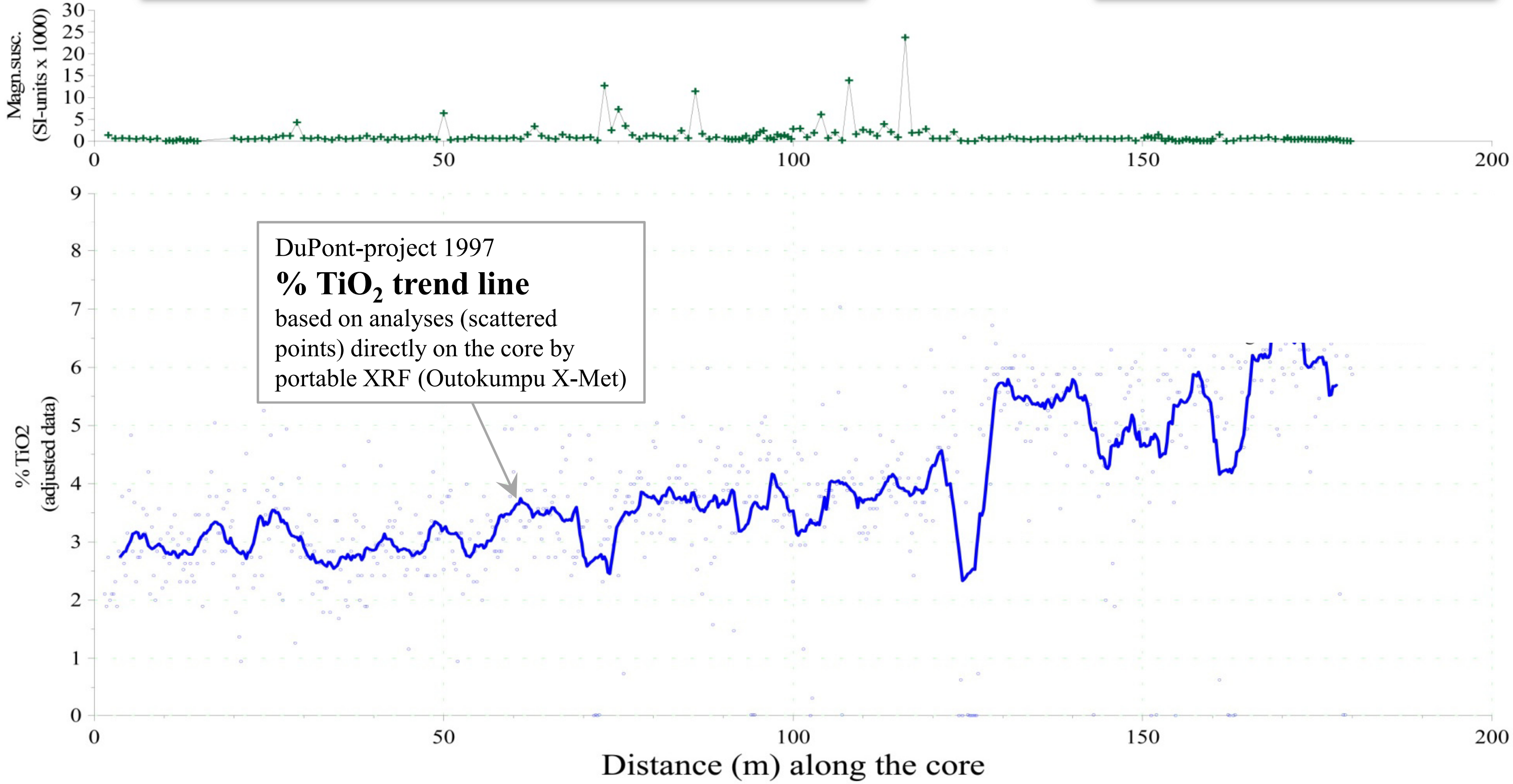
Comments Dh5

- Distinct magnetic susceptibility in parts of the core indicate retrograde alteration.
- After 120m magnetic susceptibility is very low and no significant retrograde alteration is expected.
- Rutile procedure analyses have not been carried out on samples from this core.

Engebøfjellet core information

Borehole 5

DuPont-NGU project 1995-97



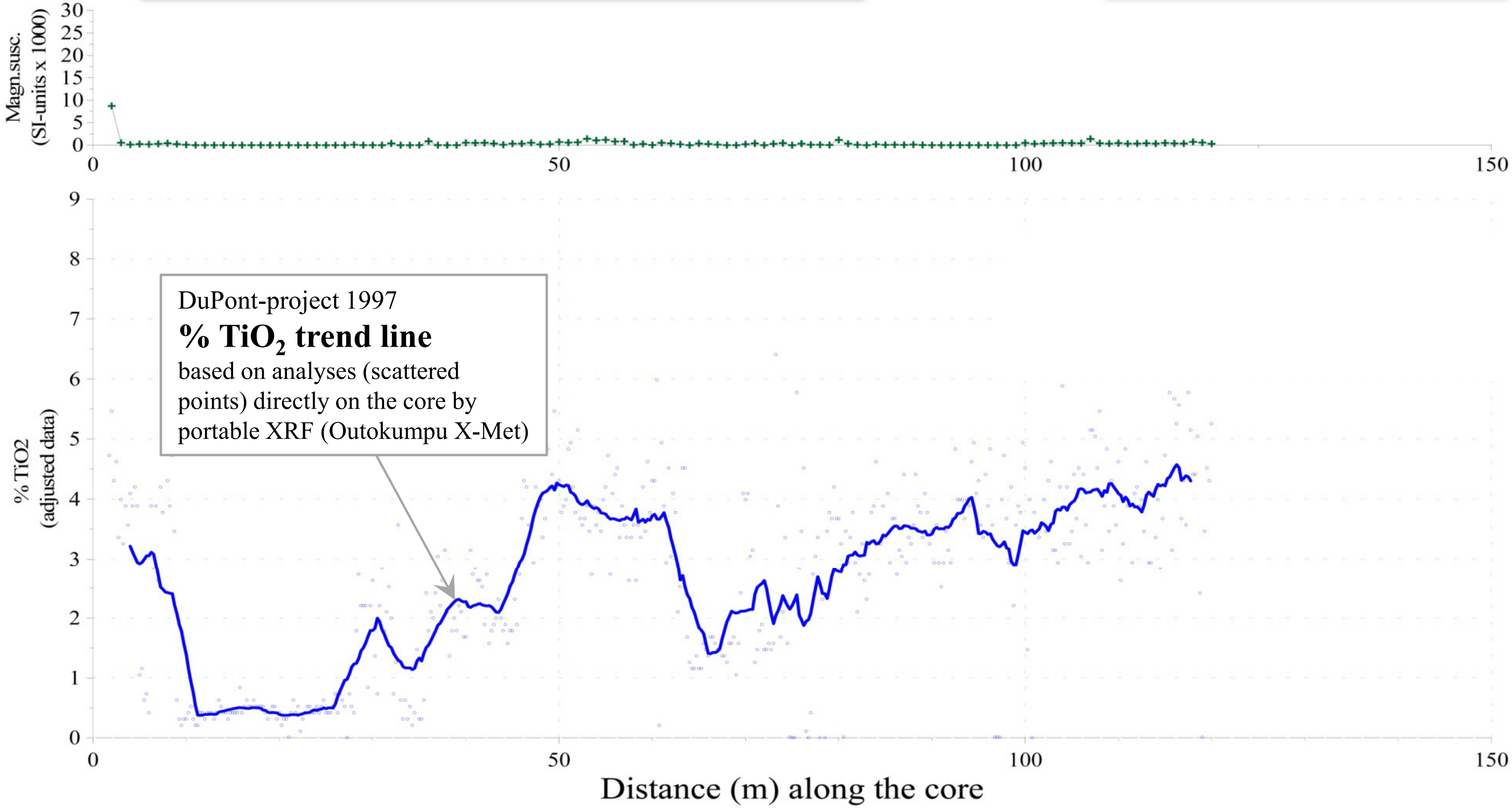
Comments Dh6

- Magnetic susceptibility is low in all parts of this core indicating no significant retrograde alteration.
- Rutile procedure analyses have not been carried out on samples from this core.

Engebøfjellet core information

Borehole 6

DuPont-NGU project 1995-97



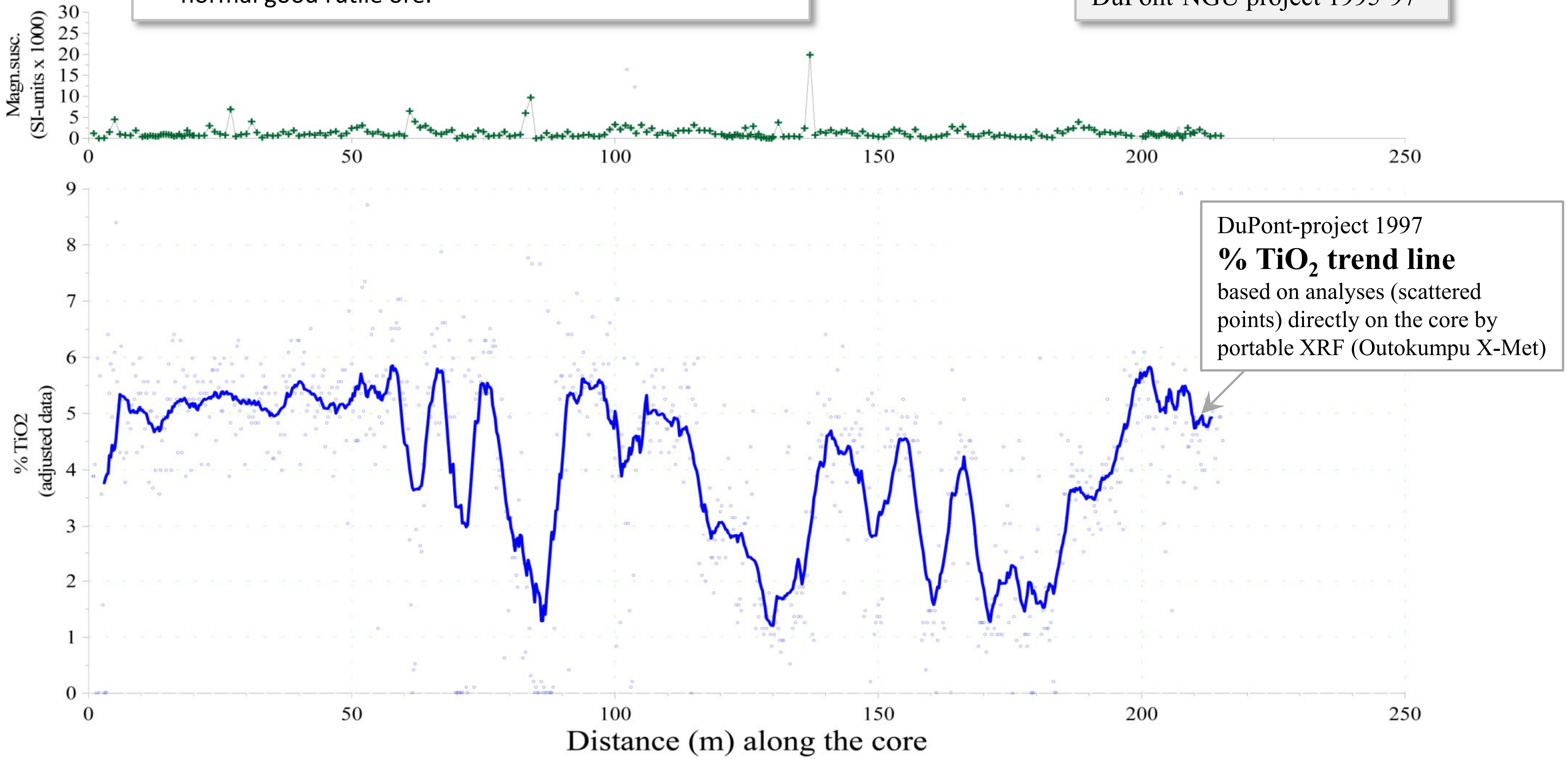
Comments Dh7

- Distinct magnetic susceptibility in parts of the core indicate some retrograde alteration.
- Rutile procedure analyses have not been carried out on samples from this core.
- The TiO_2-rich parts of this core are expected to be normal good rutile ore.

Engebøfjellet core information

Borehole 7

DuPont-NGU project 1995-97



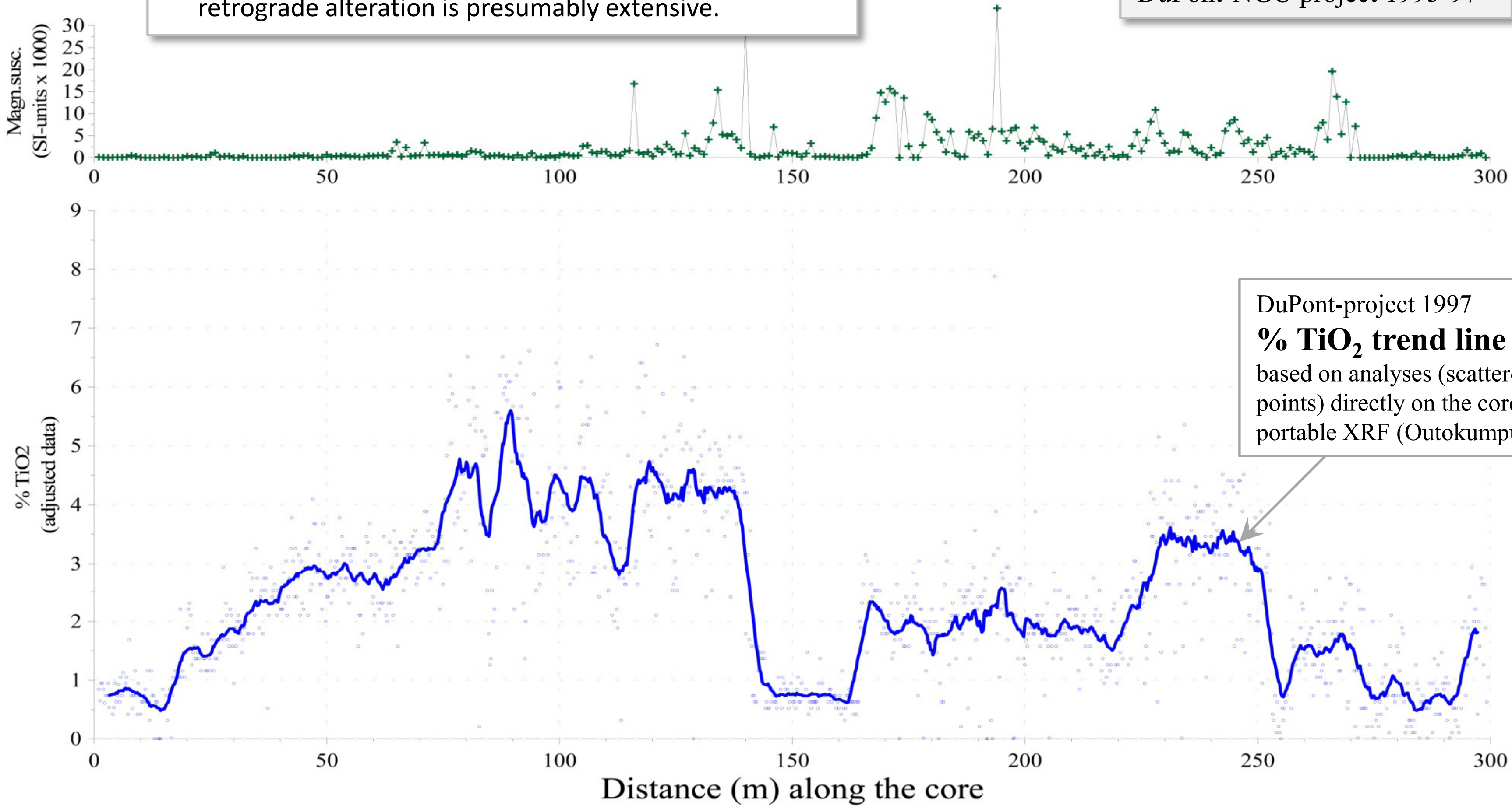
Comments Dh8

- Distinct magnetic susceptibility in large parts of the core indicate retrograde alteration.
- Rutile procedure analyses have not been carried out on samples from this core.
- The TiO_2-rich parts of this core up to approx. 110 m are expected to be fairly good rutile ore; after that retrograde alteration is presumably extensive.

Engebøfjellet core information

Borehole 8

DuPont-NGU project 1995-97



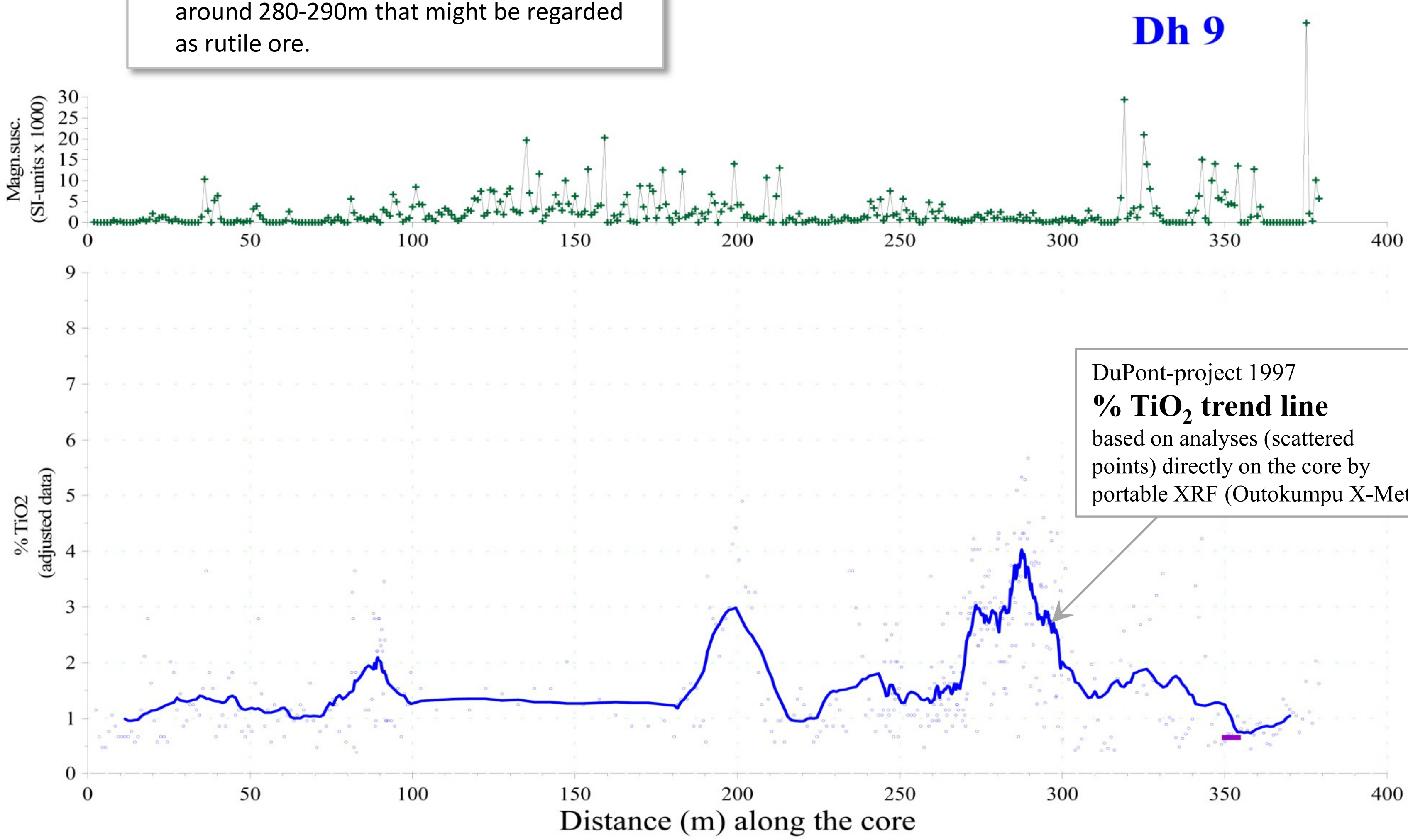
Engebøfjellet core information

Borehole 9

DuPont-NGU project 1995-97

Comments Dh9

- Low-TiO2, mainly country-rock except around 280-290m that might be regarded as rutile ore.



Comments Dh10

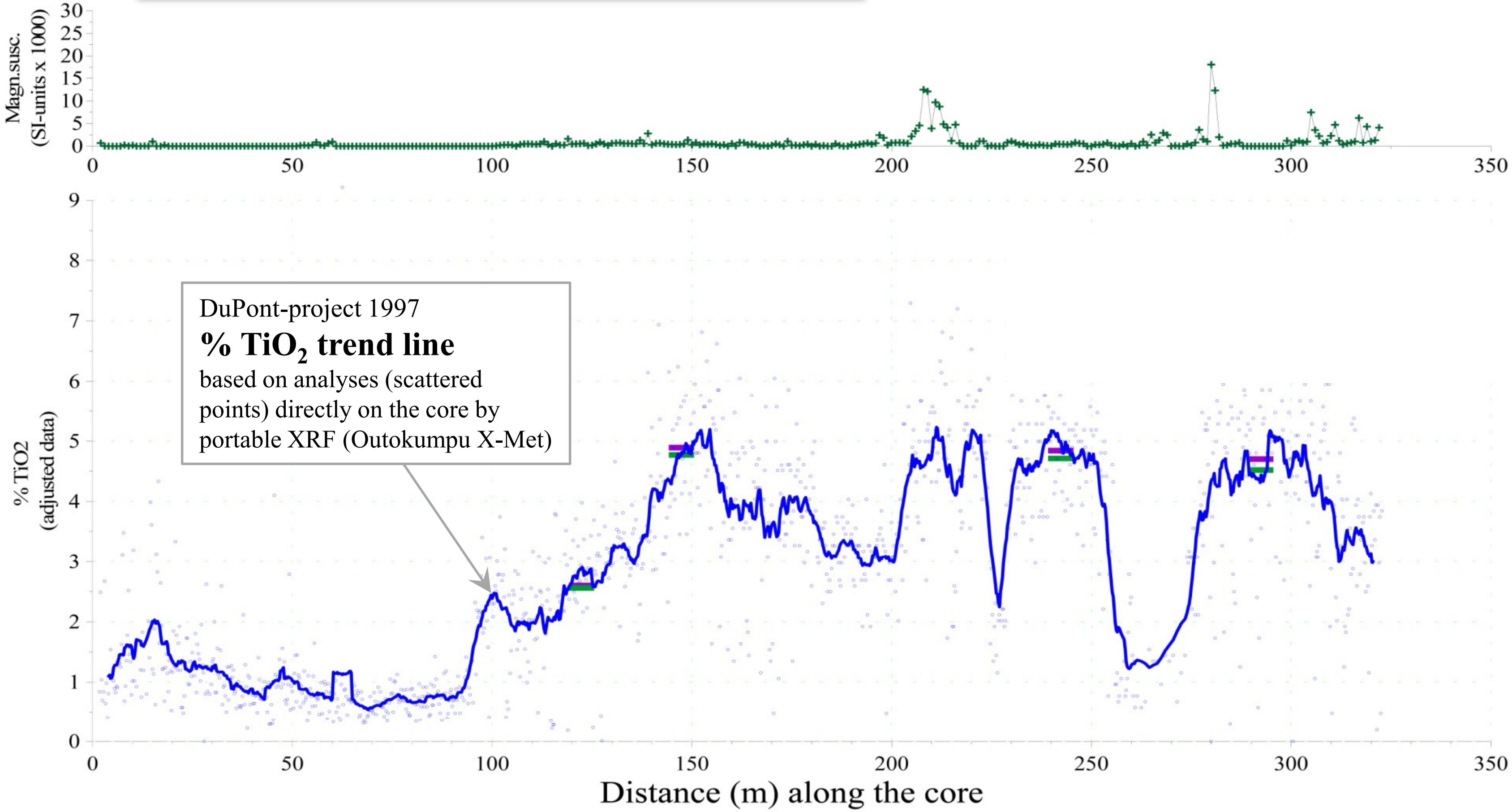
- Distinct magnetic susceptibility in some parts of the core indicate retrograde alteration.
- Four rutile procedure analyses from parts of the core with low magnetic susceptibility show high rutile vs. TiO_2 (see Appendix 2 and 3) .

Engebøfjellet core information

Borehole 10

DuPont-NGU project 1995-97

Dh 10



Comments Dh11

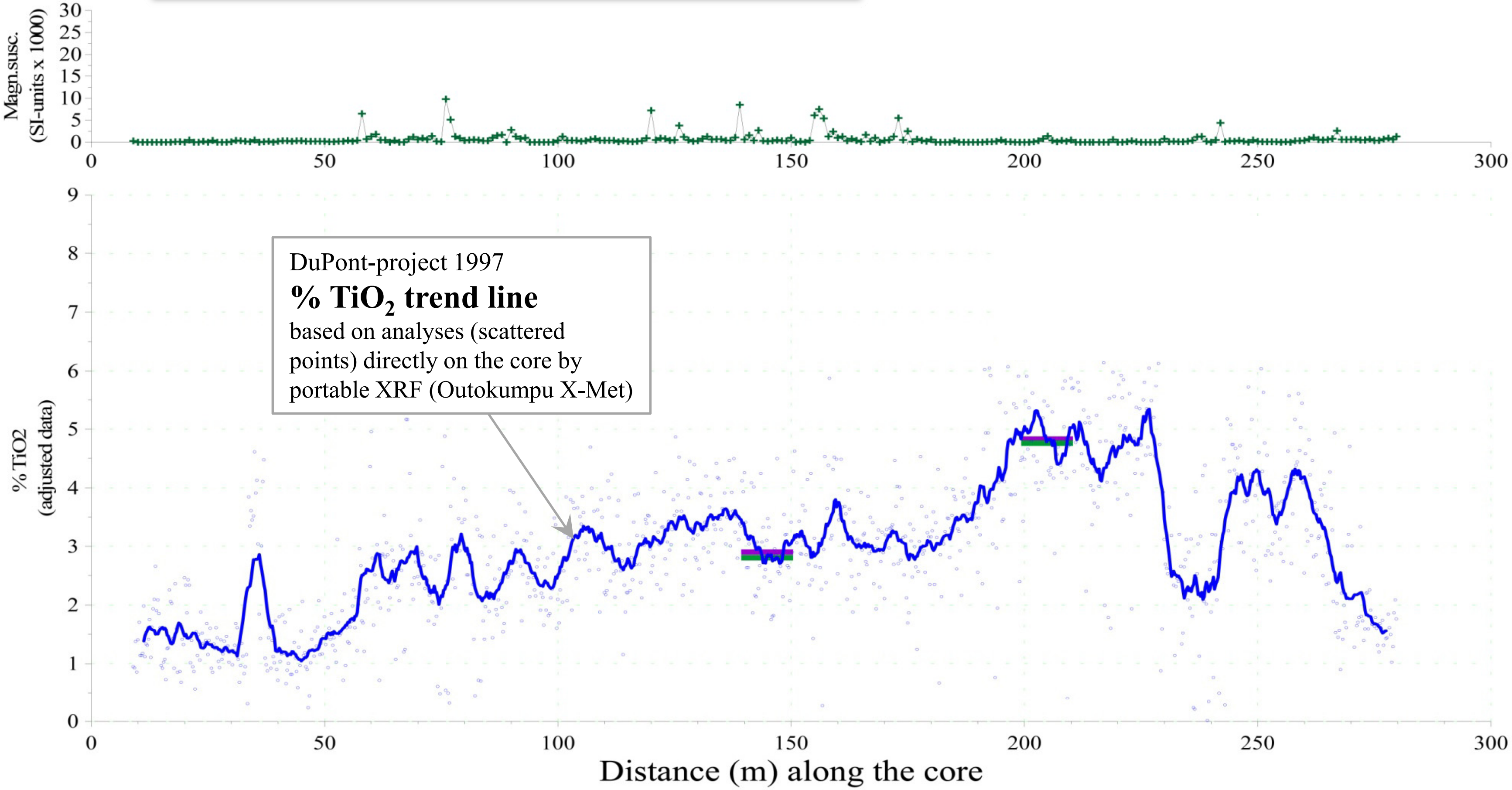
- Distinct magnetic susceptibility in some parts of the core indicate retrograde alteration.
- Two rutile procedure analyses show high rutile vs. TiO_2 (see Appendix 2 and 3).
- The high-TiO_2 parts of the core is expected to represent good rutile ore.

Engebøfjellet core information

Borehole 11

DuPont-NGU project 1995-97

Dh 11



Comments Dh12

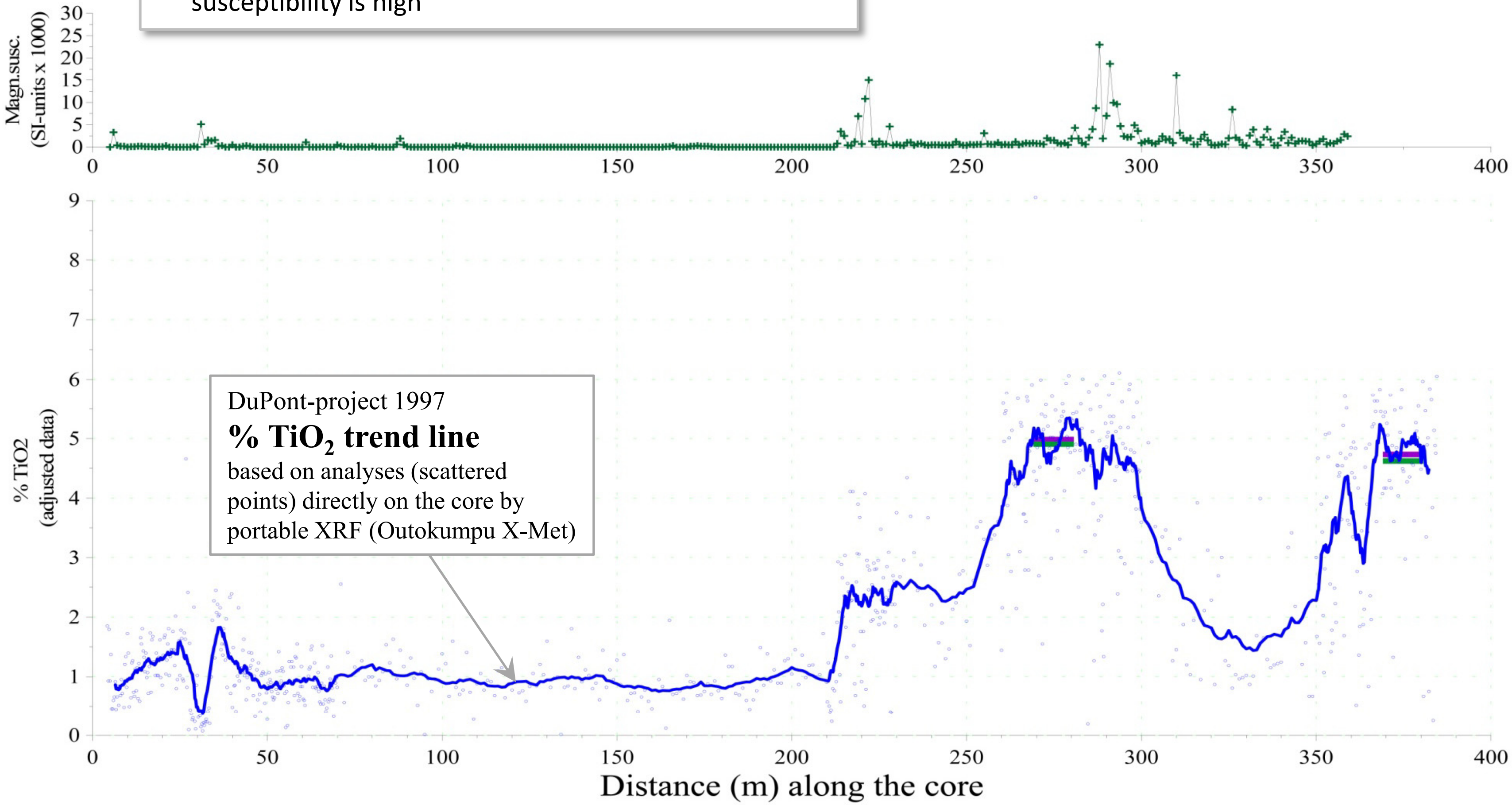
- Distinct magnetic susceptibility in parts of the core indicate retrograde alteration.
- Two rutile procedure analyses show high rutile vs. TiO_2 (see Appendix 2 and 3).
- The high-TiO_2 parts of the core is expected to represent good rutile ore, except may be where the magnetic susceptibility is high

Engebøfjellet core information

Borehole 12

DuPont-NGU project 1995-97

Dh 12



Engebøfjellet core information

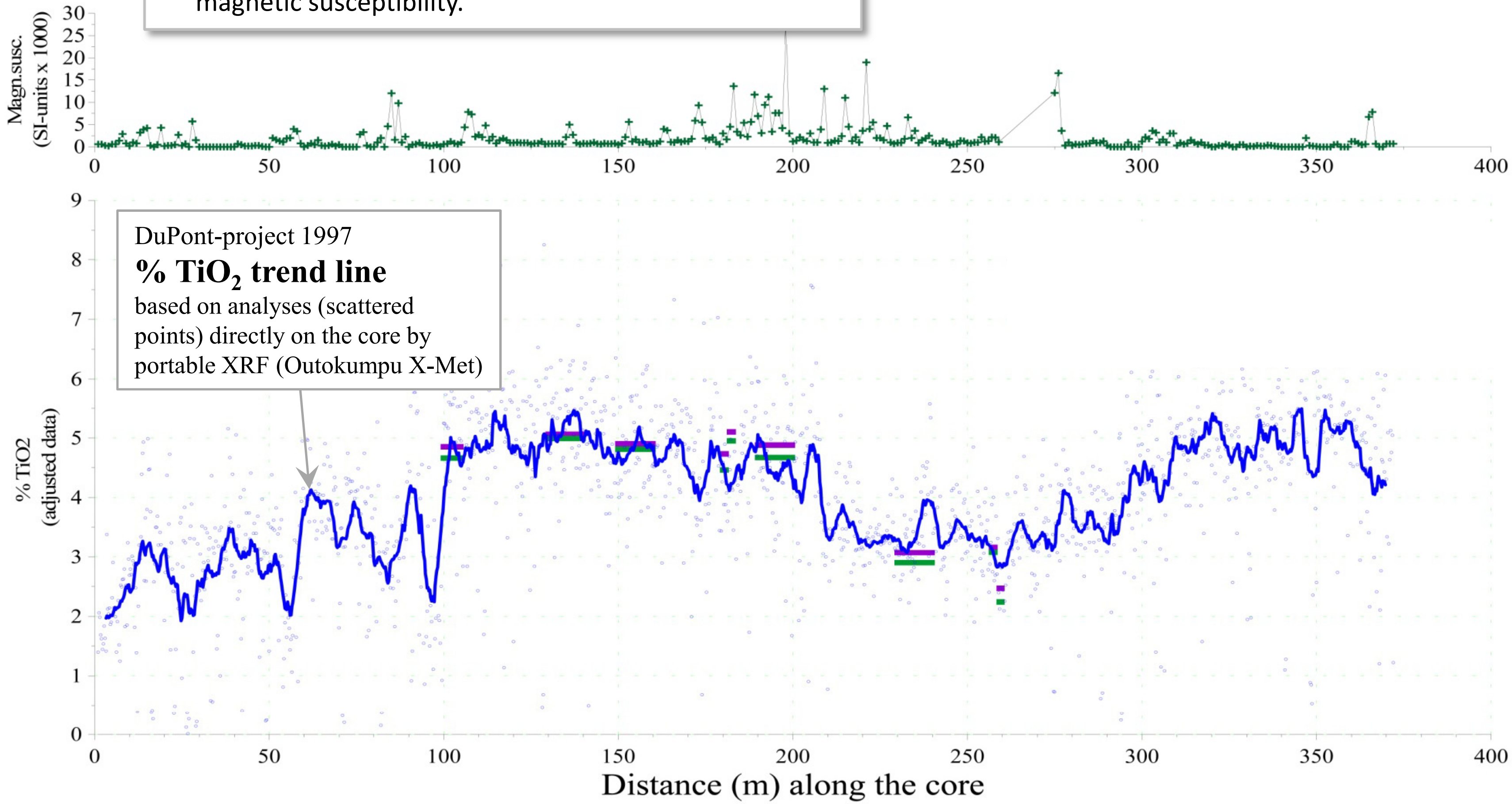
Borehole 13

DuPont-NGU project 1995-97

Comments Dh13

- Distinct magnetic susceptibility in parts of the core indicate retrograde alteration.
- Nine rutile procedure analyses show high rutile vs. TiO_2 (see Appendix 2 and 3).
- The high-TiO_2 parts of the core is expected to represent good rutile ore, except may be locally in parts with high magnetic susceptibility.

Dh 13



Comments Dh14

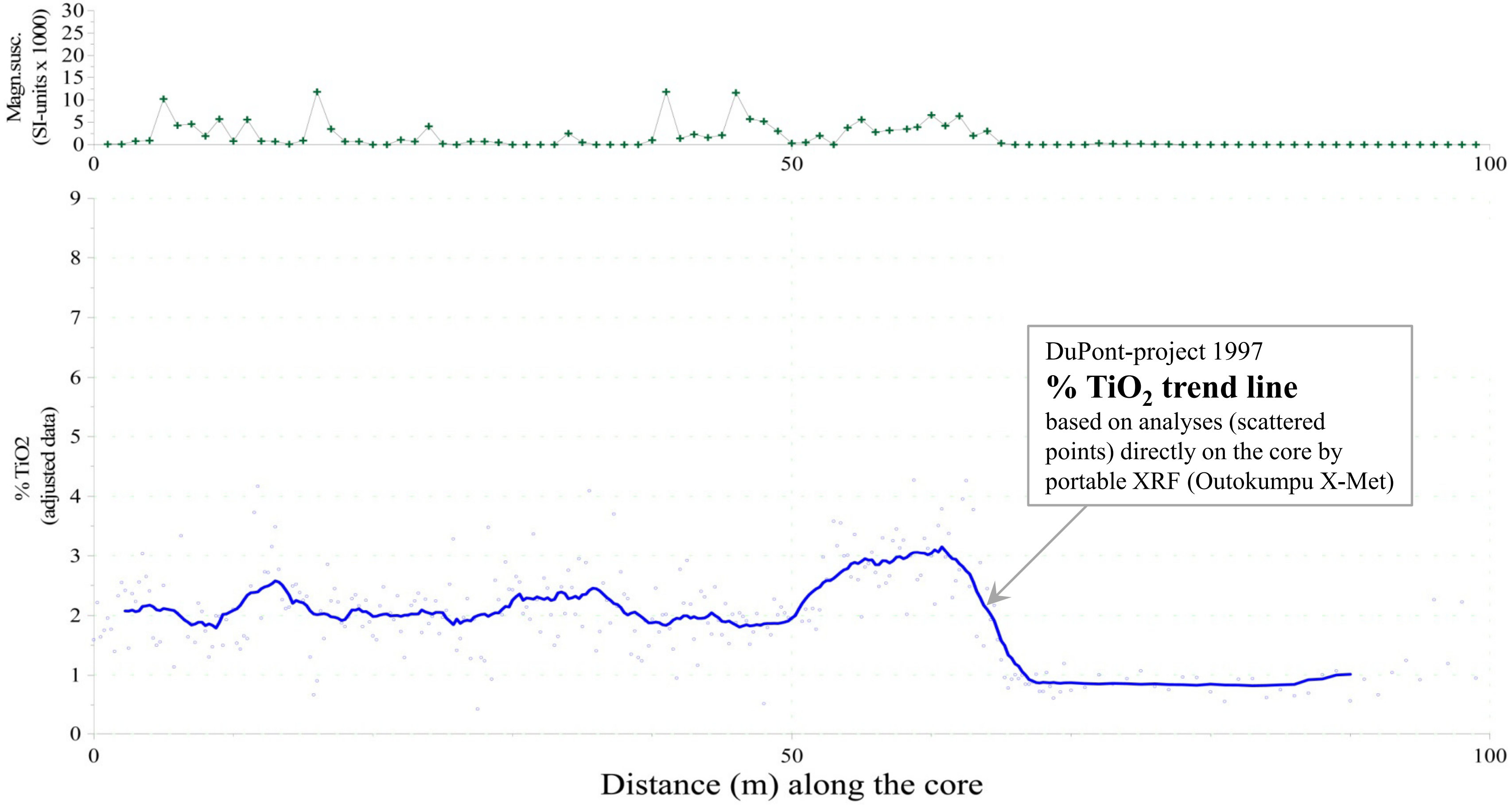
- Distinct magnetic susceptibility in parts of the core indicate retrograde alteration.
- No rutile procedure analyses is available.
- Due to low TiO_2 this core is not of ore quality, except may be around 60-70 meters.

Engebøfjellet core information

Borehole 14

DuPont-NGU project 1995-97

Dh 14



Comments Dh15

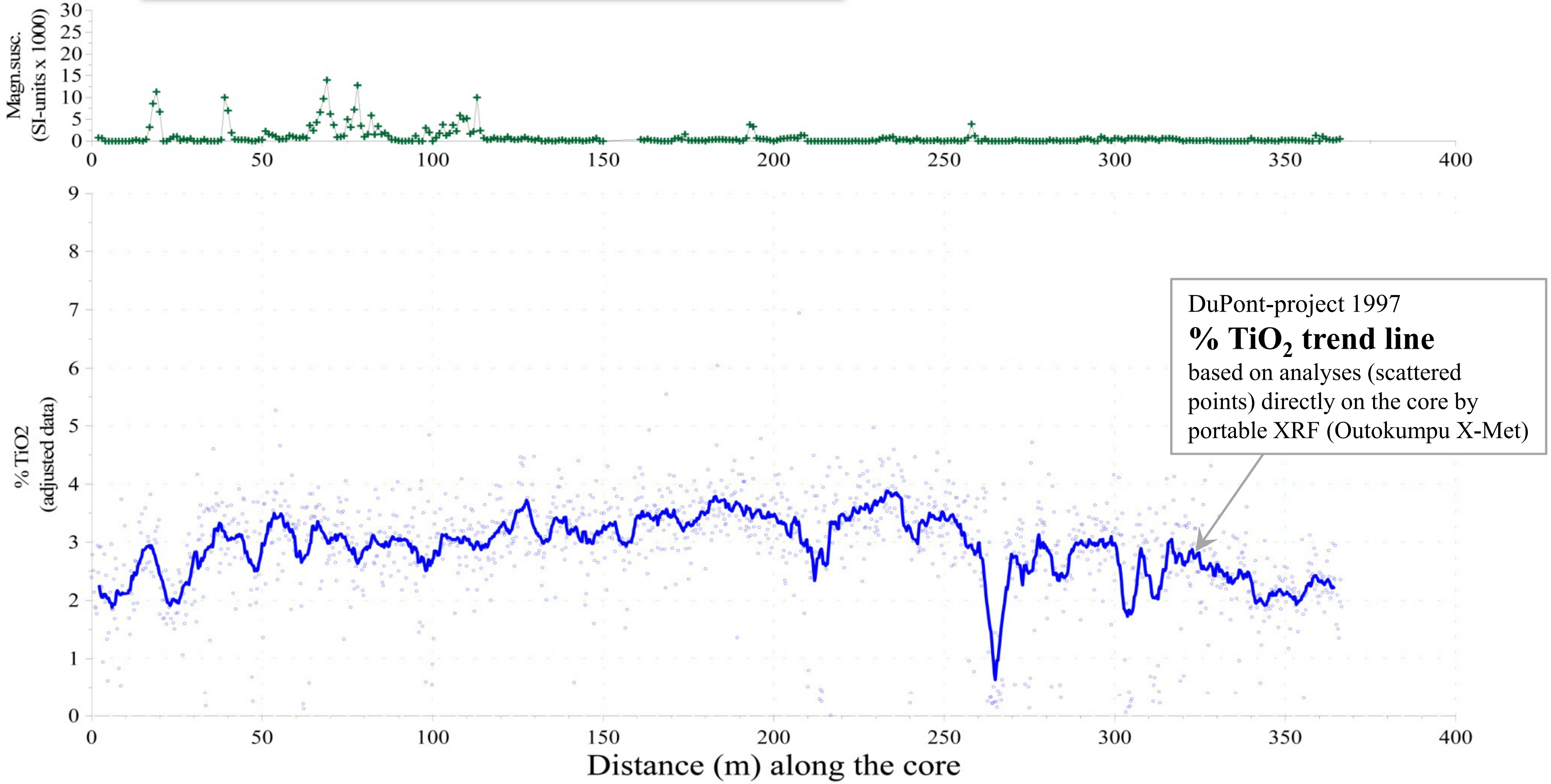
- Distinct magnetic susceptibility particularly in the first 100m indicate retrograde alteration.
- No rutile procedure analyses are available.
- In general the core is of “transitional” eclogite type.

Engebøfjellet core information

Borehole 15

DuPont-NGU project 1995-97

Dh 15



Comments Dh16

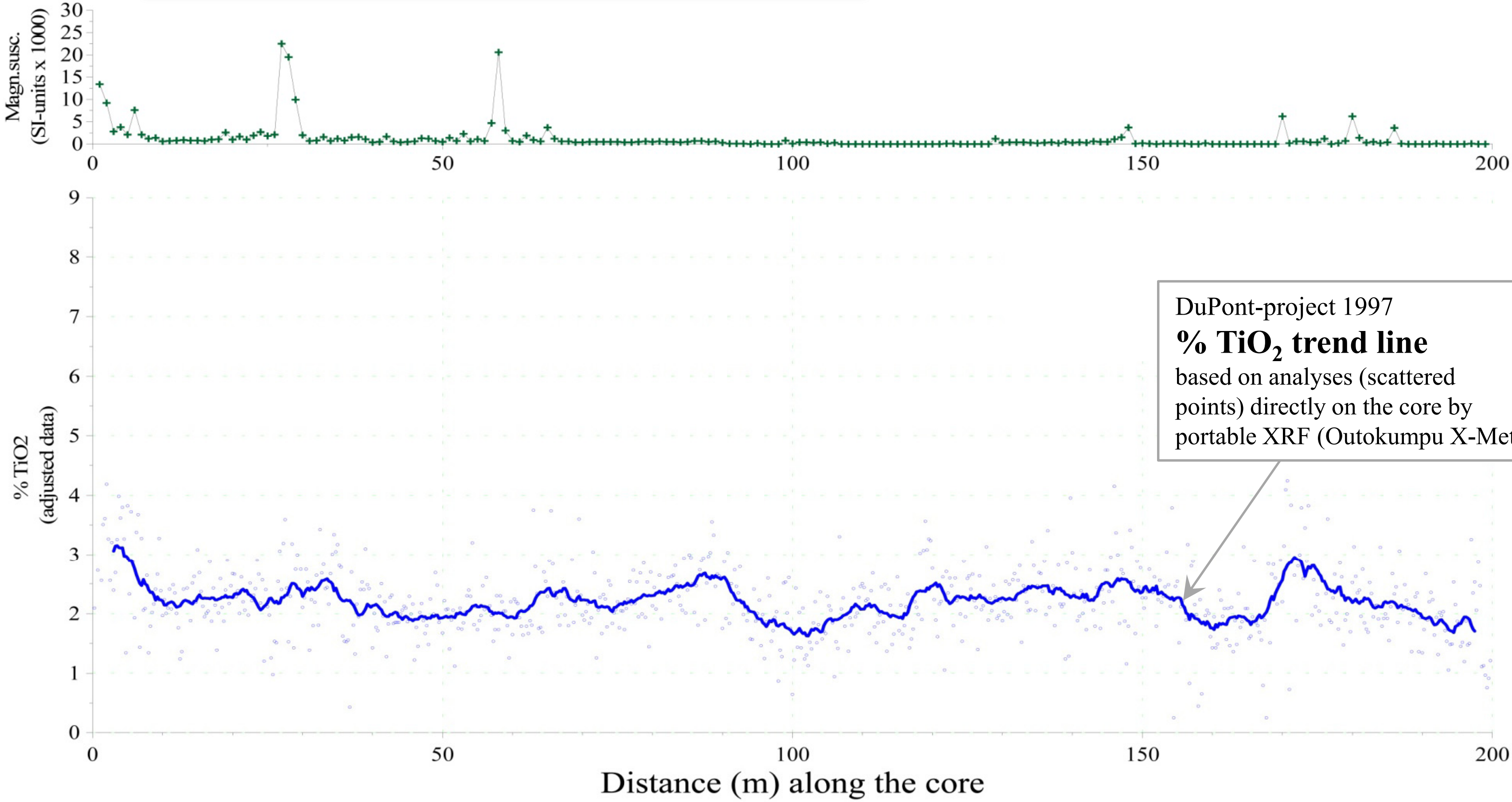
- Distinct magnetic susceptibility in some parts indicating retrograde alteration.
- No rutile procedure analyses are available.
- In general the core is of “leuco” to “transitional” eclogite type.

Engebøfjellet core information

Borehole 16

DuPont-NGU project 1995-97

Dh 16



Comments Dh17

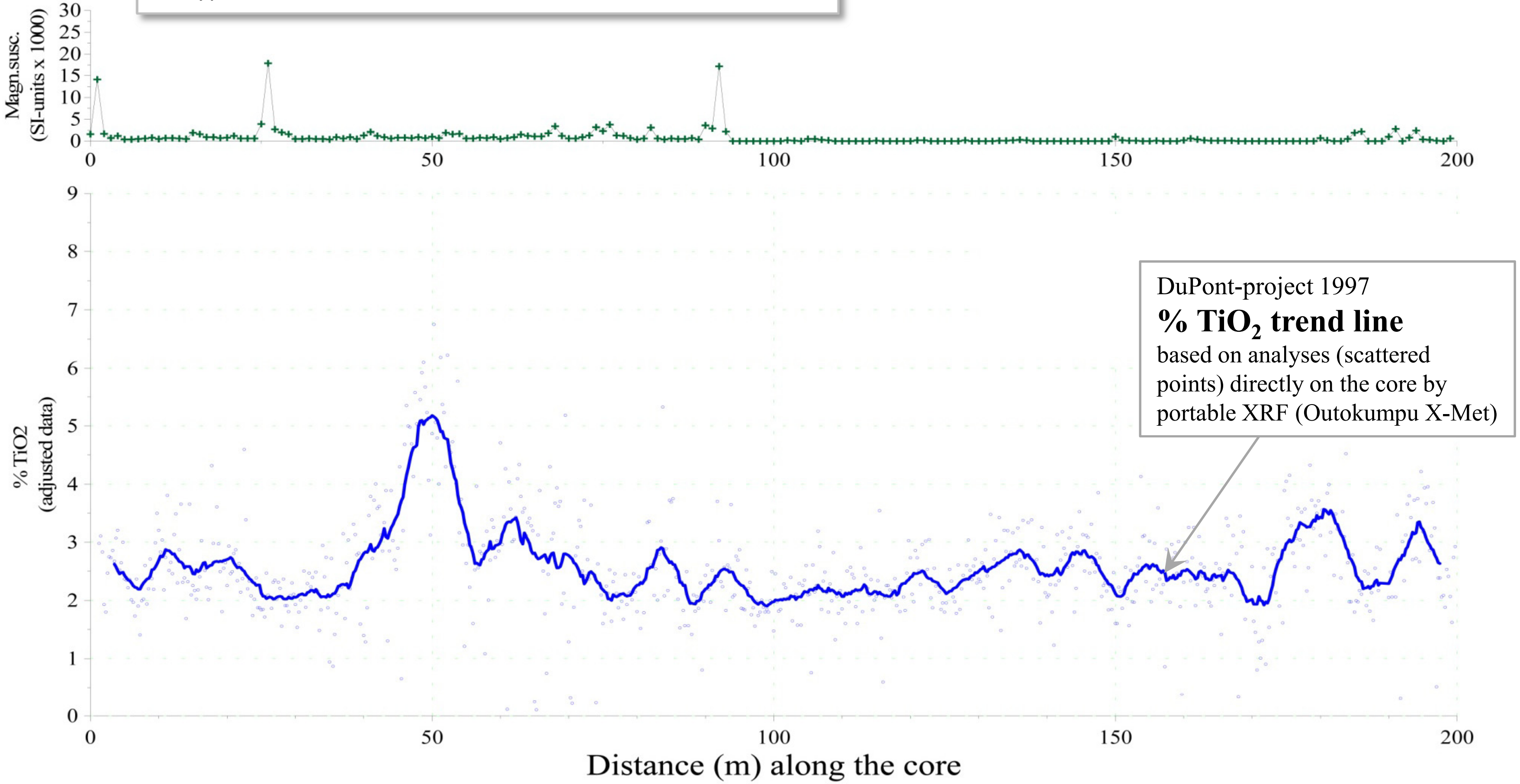
- Distinct magnetic susceptibility in some parts indicating retrograde alteration.
- No rutile procedure analyses are available.
- In general the core is of “leuco” to “transitional” eclogite type except around 50m that is of rutile ore type.

Engebøfjellet core information

Borehole 17

DuPont-NGU project 1995-97

Dh 17



Comments Dh101

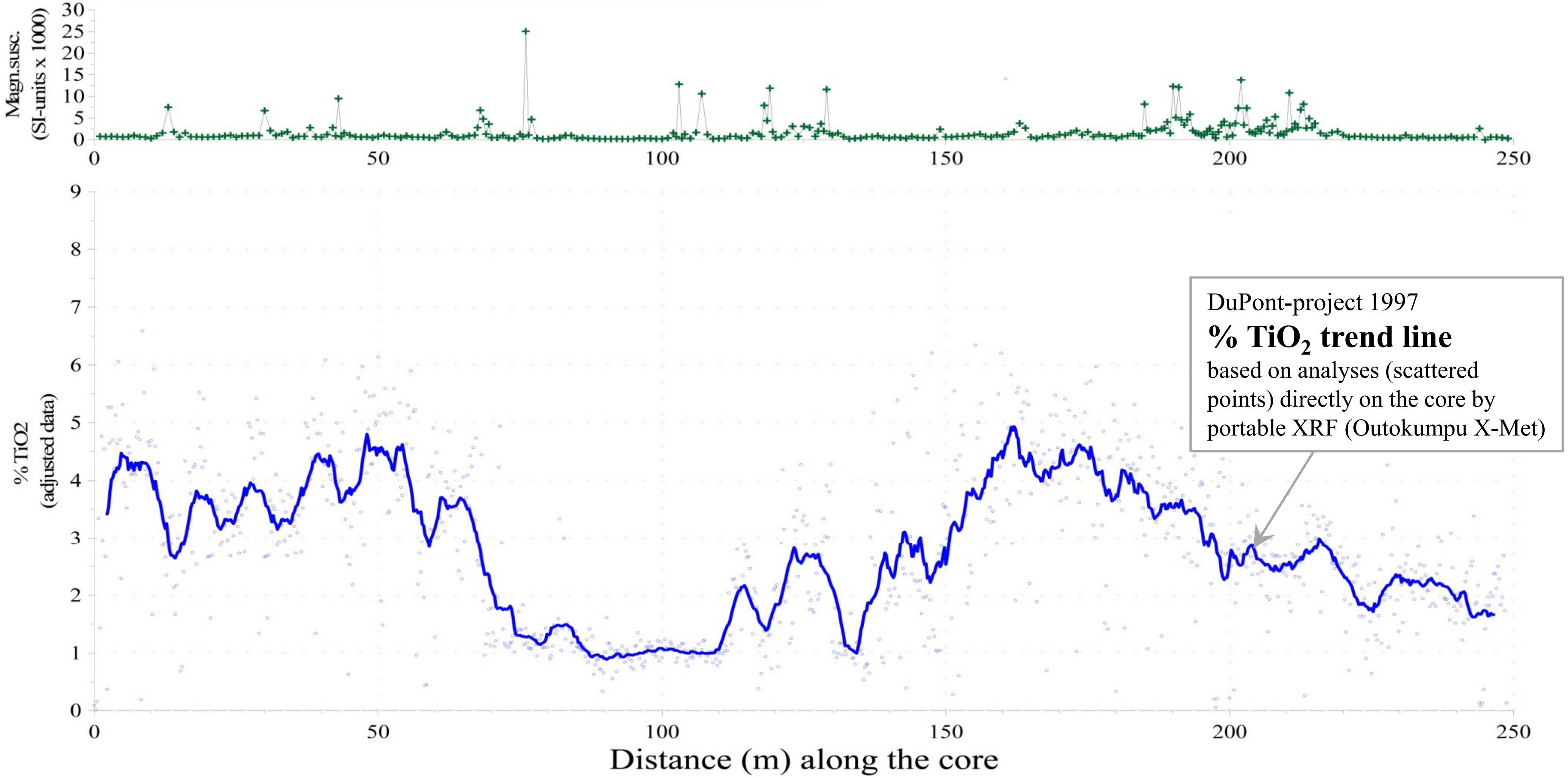
- Distinct magnetic susceptibility in some parts indicating retrograde alteration.
- No rutile procedure analyses are available.
- In general core-sections with more than 3 % TiO_2 might be regarded to be of ore quality.

Engebøfjellet core information

Borehole 101

DuPont-NGU project 1995-97

Dh 101



Comments Dh102

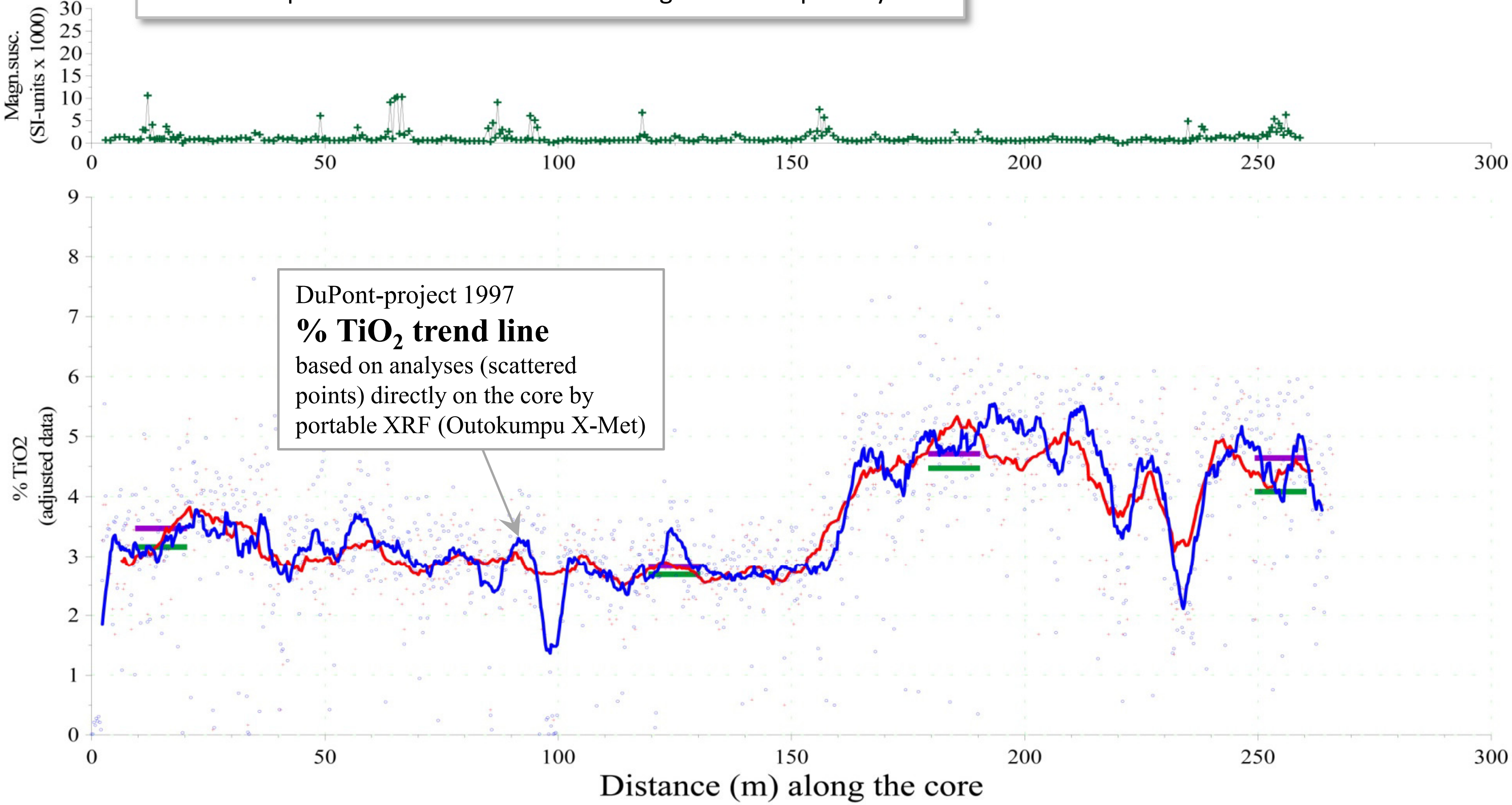
- Distinct magnetic susceptibility in some parts indicating retrograde alteration.
- Four rutile procedure analyses are available; in the high-TiO_2 parts of the core two rutile analyses are available showing Rutile/TiO2 = 0.95 (180-190m) and 0.88 (150-260). The latter is probably significantly affected by retrograde alteration, and is within a part of the core with distinct magnetic susceptibility.

Engebøfjellet core information

Borehole 102

DuPont-NGU project 1995-97

Dh 102



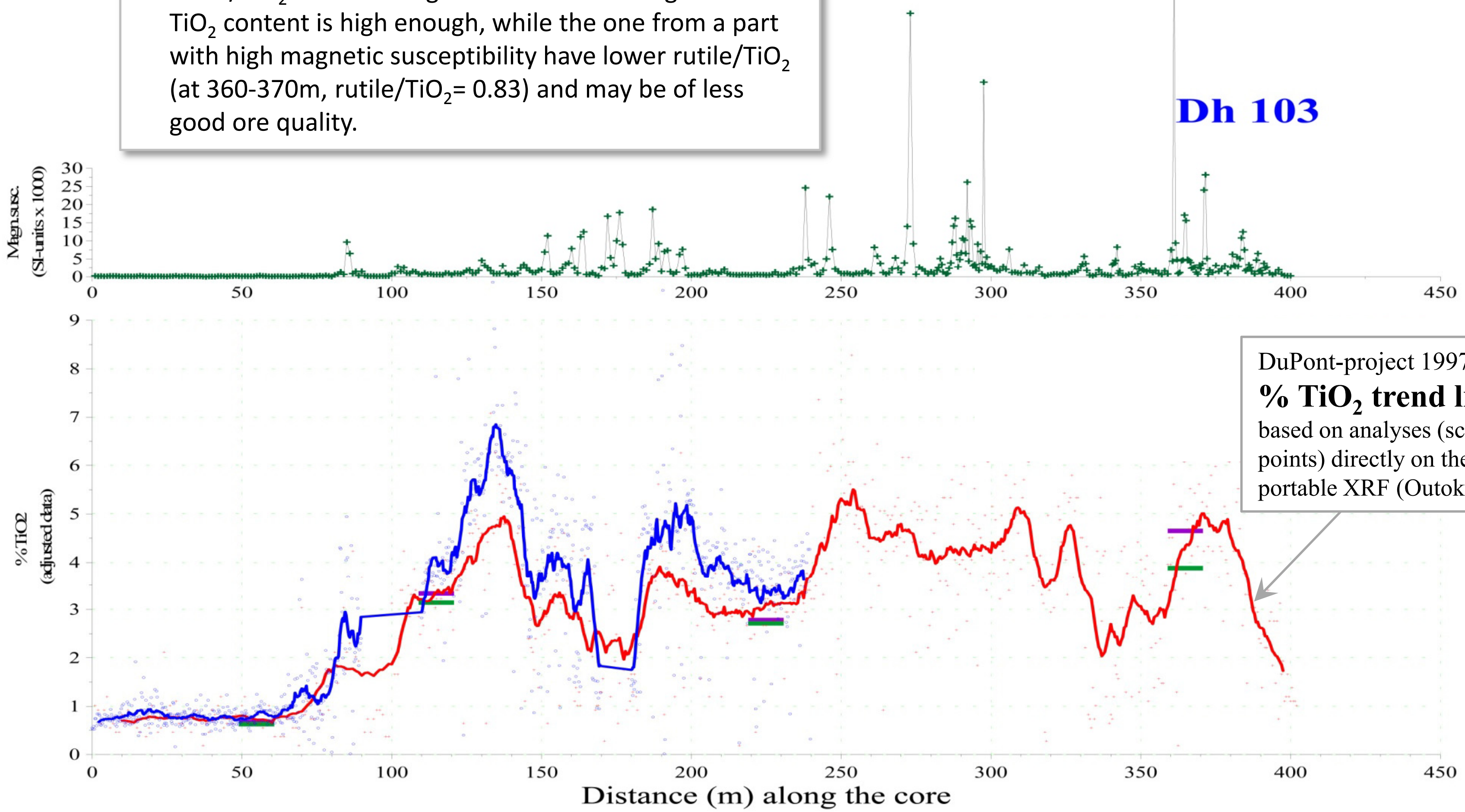
Comments Dh102

- Very distinct magnetic susceptibility in some parts indicating retrograde alteration.
- Four rutile procedure analyses are available (Appendix 2 and 3). Those analysed samples that are from parts of the core with low magnetic susceptibility have a high rutile/TiO_2-ratio and is good rutile ore as long as the TiO_2 content is high enough, while the one from a part with high magnetic susceptibility have lower rutile/TiO_2 (at 360-370m, rutile/TiO_2= 0.83) and may be of less good ore quality.

Engebøfjellet core information

Borehole 103

DuPont-NGU project 1995-97



DuPont-project 1997

% TiO_2 trend line

based on analyses (scattered points) directly on the core by portable XRF (Outokumpu X-Met)

Comments Dh104

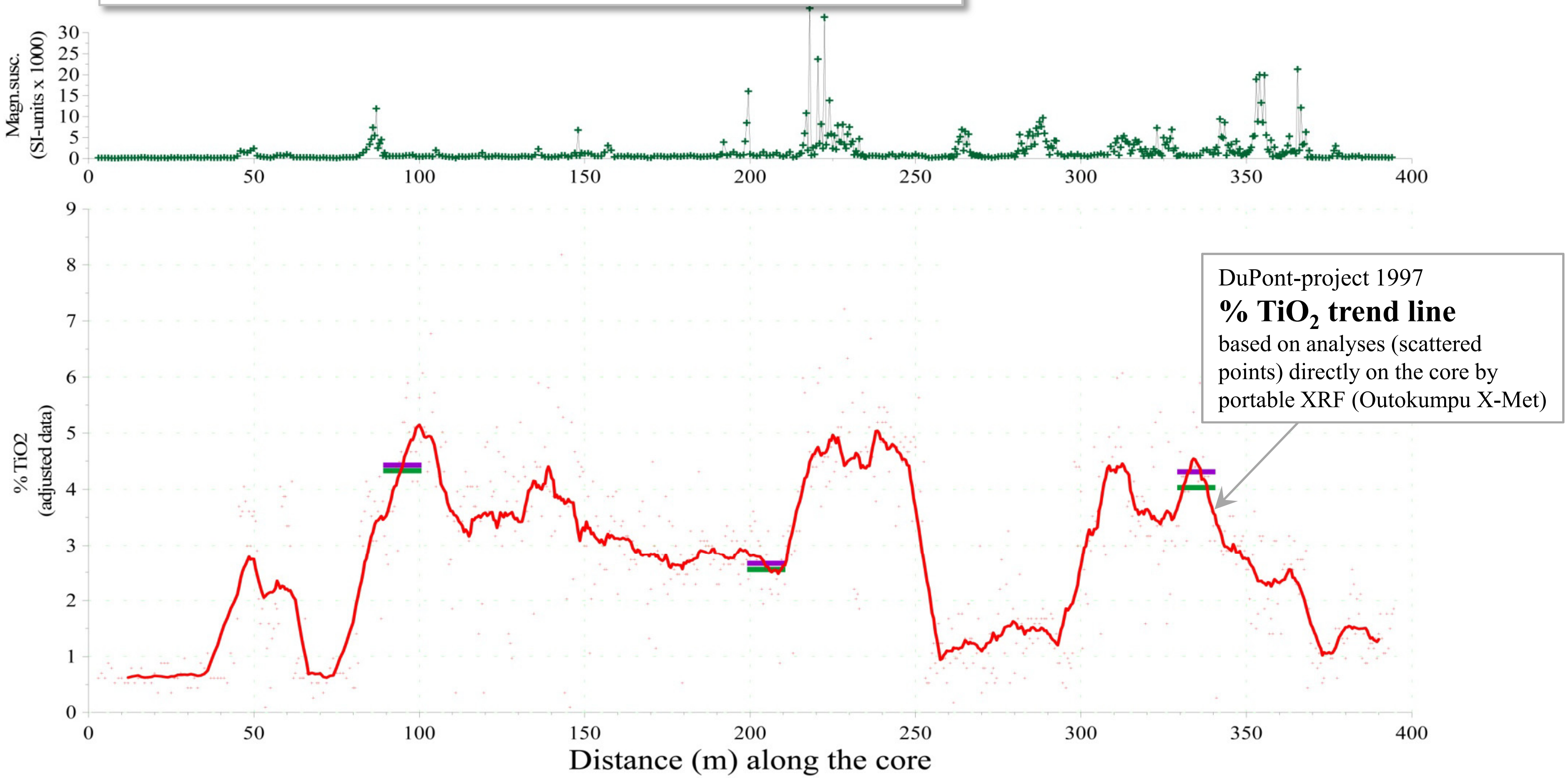
- Distinct magnetic susceptibility in some parts of the core indicating retrograde alteration.
- Rutile procedure analyses are from samples with fairly low magnetic susceptibility and have high rutile/TiO_2 ratios (see Appendix 2 and 3).
- Presumably the rutile ore quality in ore zones with high magnetic susceptibility is reduced.

Engebøfjellet core information

Borehole 104

DuPont-NGU project 1995-97

Dh 104



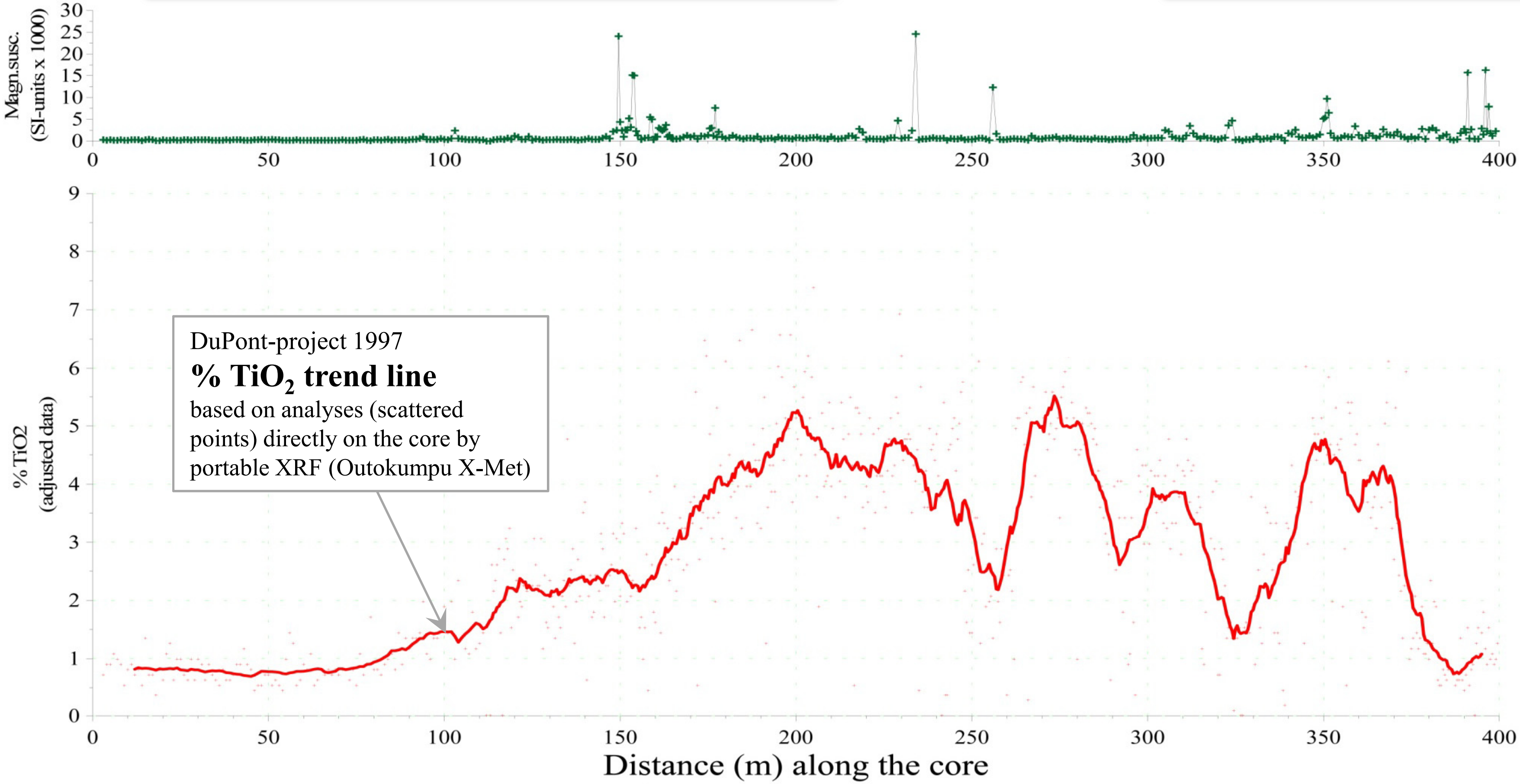
Comments Dh105

- Distinct magnetic susceptibility in some parts of the core indicating retrograde alteration.
- No rutile procedure analyses are available.
- Presumably the TiO_2-rich parts of the core are good rutile ore.

Engebøfjellet core information

Borehole 105

DuPont-NGU project 1995-97



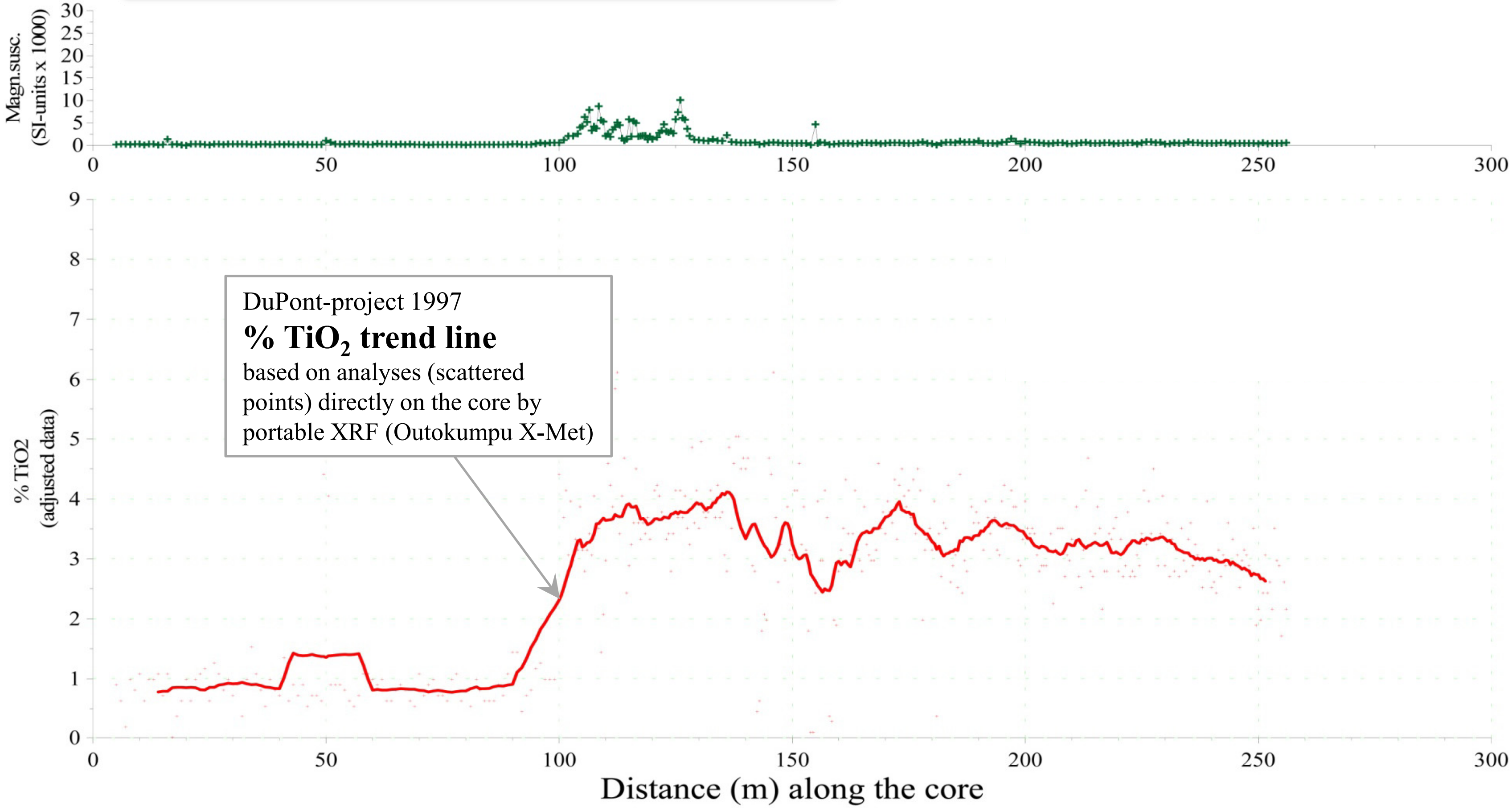
Comments Dh106

- Distinct magnetic susceptibility in some parts of the core indicating retrograde alteration.
- No rutile procedure analyses are available.
- Presumably the TiO_2-rich parts of the core are good rutile ore.

Engebøfjellet core information

Borehole 106

DuPont-NGU project 1995-97



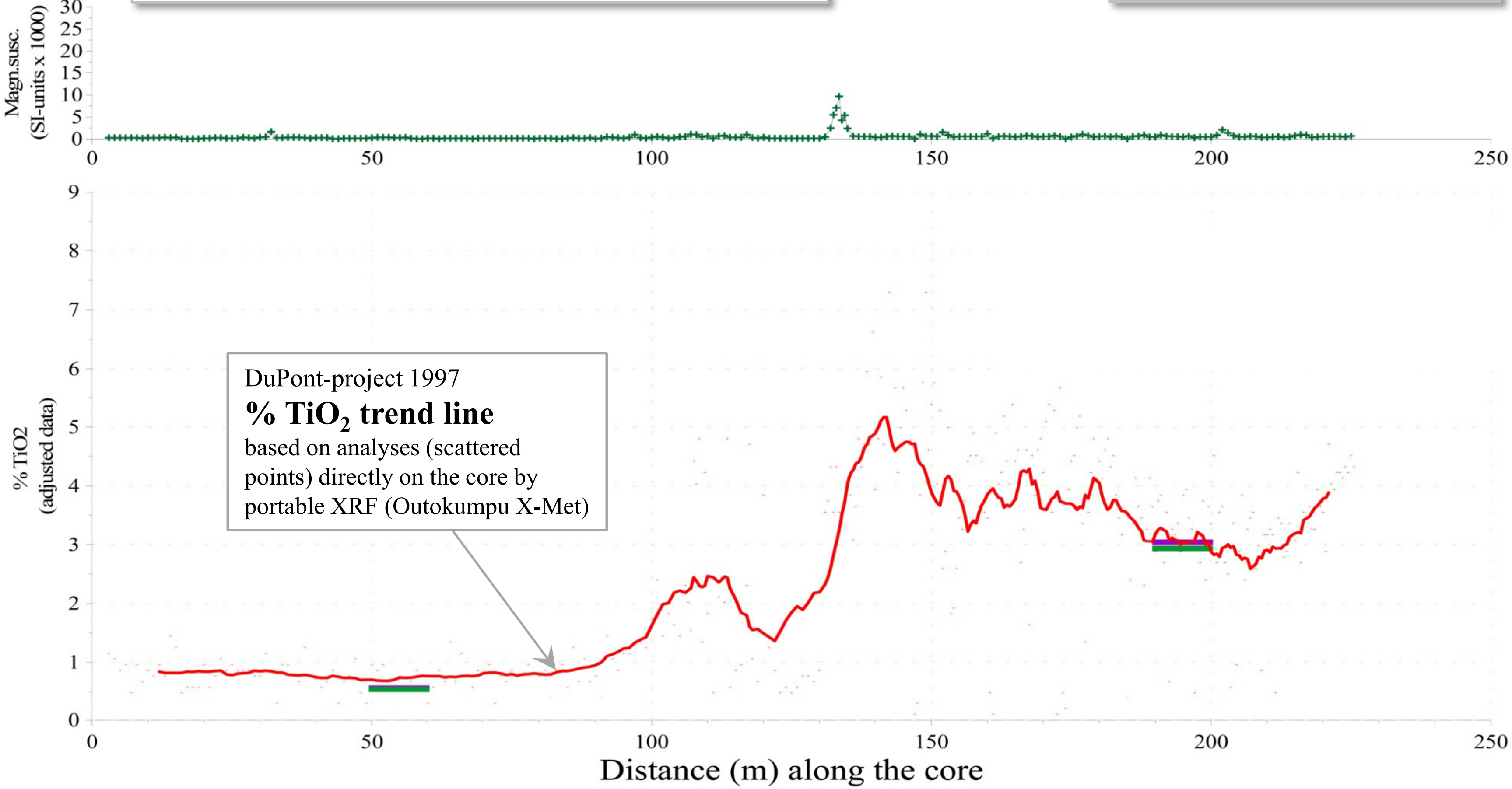
Comments Dh107

- Distinct magnetic susceptibility in a few parts of the core indicating retrograde alteration.
- The rutile procedure analysed available (Appendix 2 and 3) show high rutile/TiO_2.
- The TiO_2-rich parts of the core are presumably good rutile ore.

Engebøfjellet core information

Borehole 107

DuPont-NGU project 1995-97



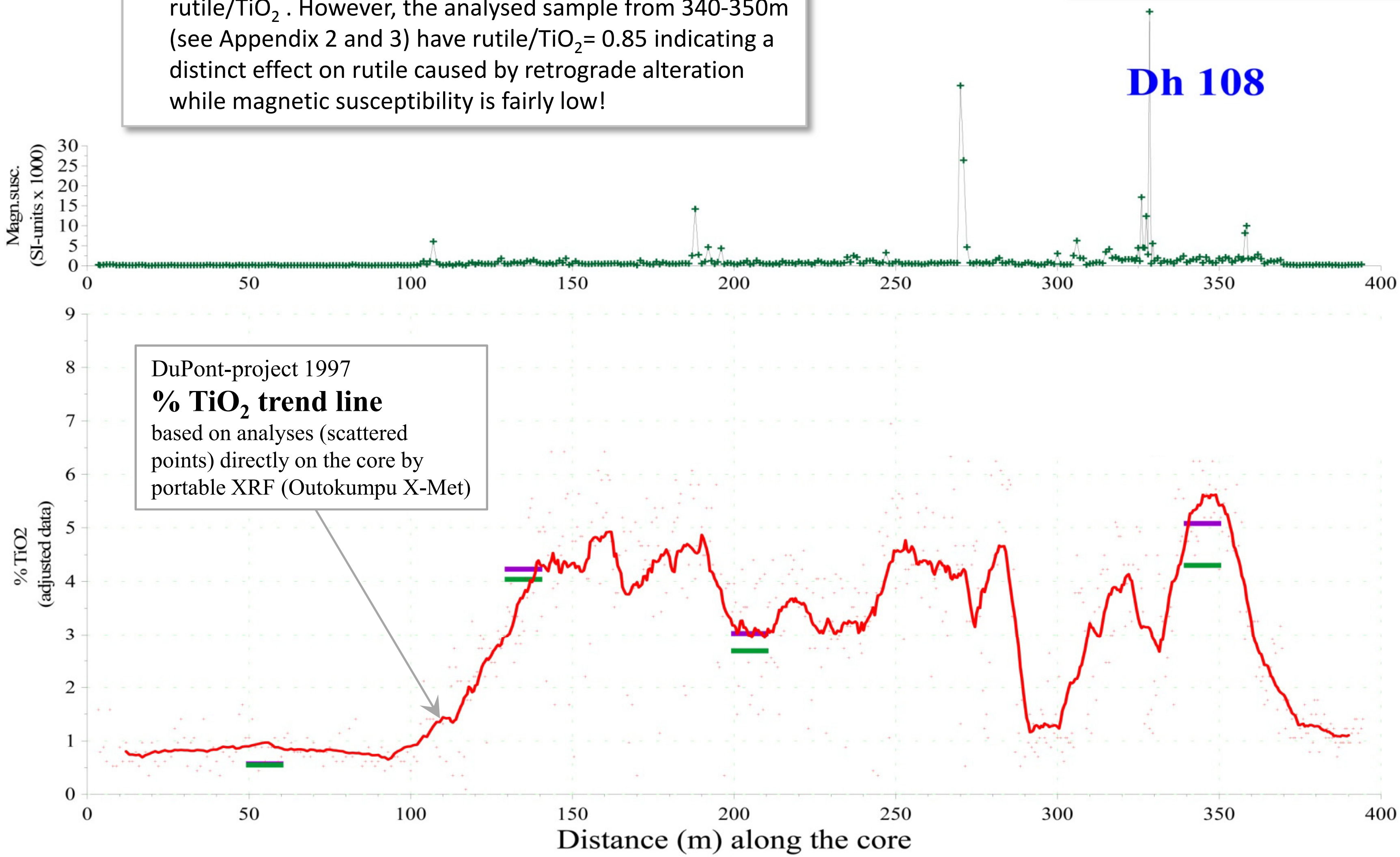
Comments Dh108

- Distinct magnetic susceptibility in a some parts of the core indicating retrograde alteration.
- The rutile procedure analysed available show fairly high rutile/TiO_2 . However, the analysed sample from 340-350m (see Appendix 2 and 3) have rutile/TiO_2= 0.85 indicating a distinct effect on rutile caused by retrograde alteration while magnetic susceptibility is fairly low!

Engebøfjellet core information

Borehole 108

DuPont-NGU project 1995-97



Comments Dh109

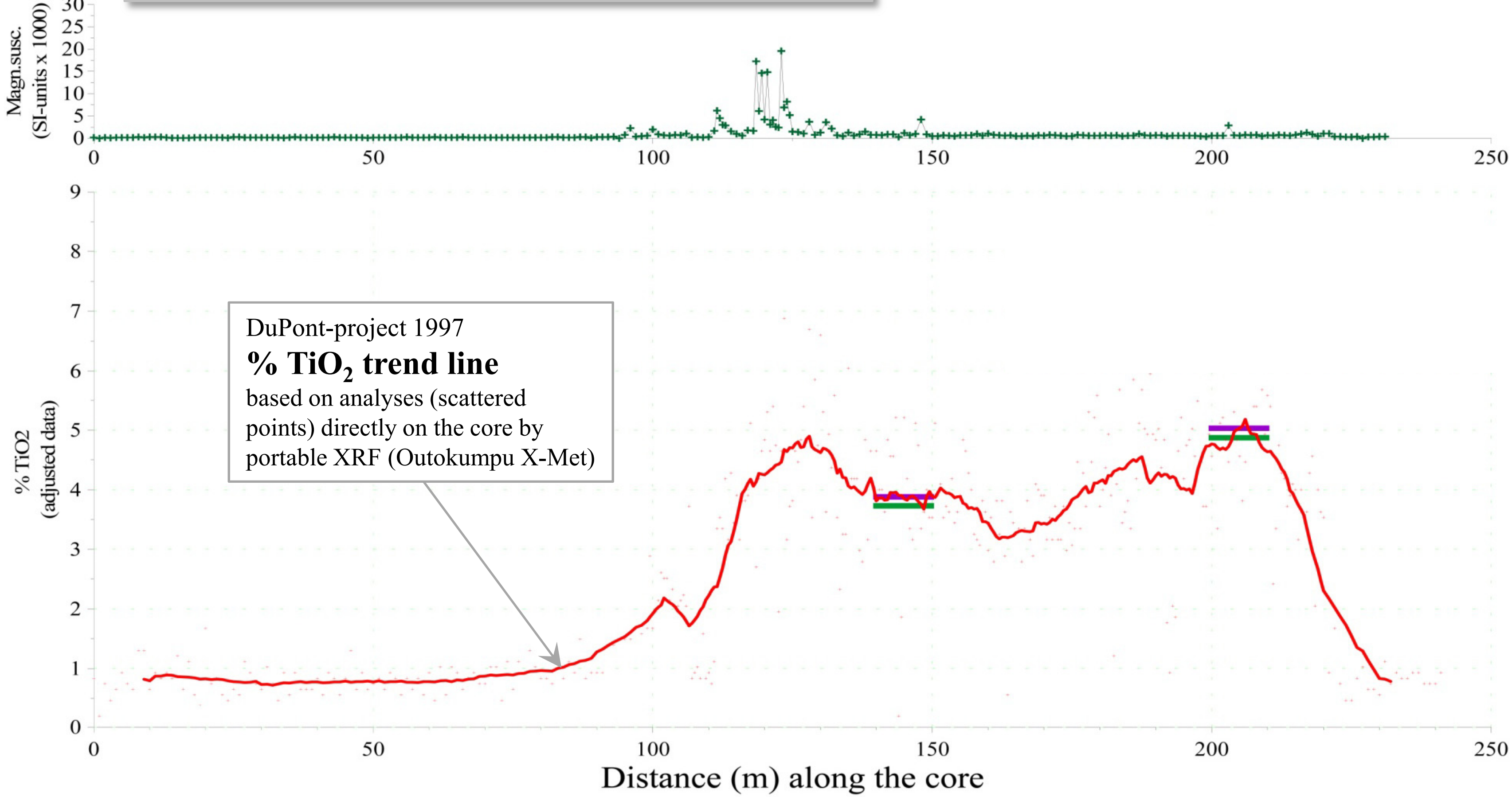
- Distinct magnetic susceptibility in a some parts of the core indicating retrograde alteration.
- The rutile procedure analysed available show high rutile/TiO_2 (see Appendix 2 and 3).
- Presumably the high-TiO_2 parts of the core are of good rutile ore quality although retrograde effects reducing ore quality is expected at around 120m.

Engebøfjellet core information

Borehole 109

DuPont-NGU project 1995-97

Dh 109



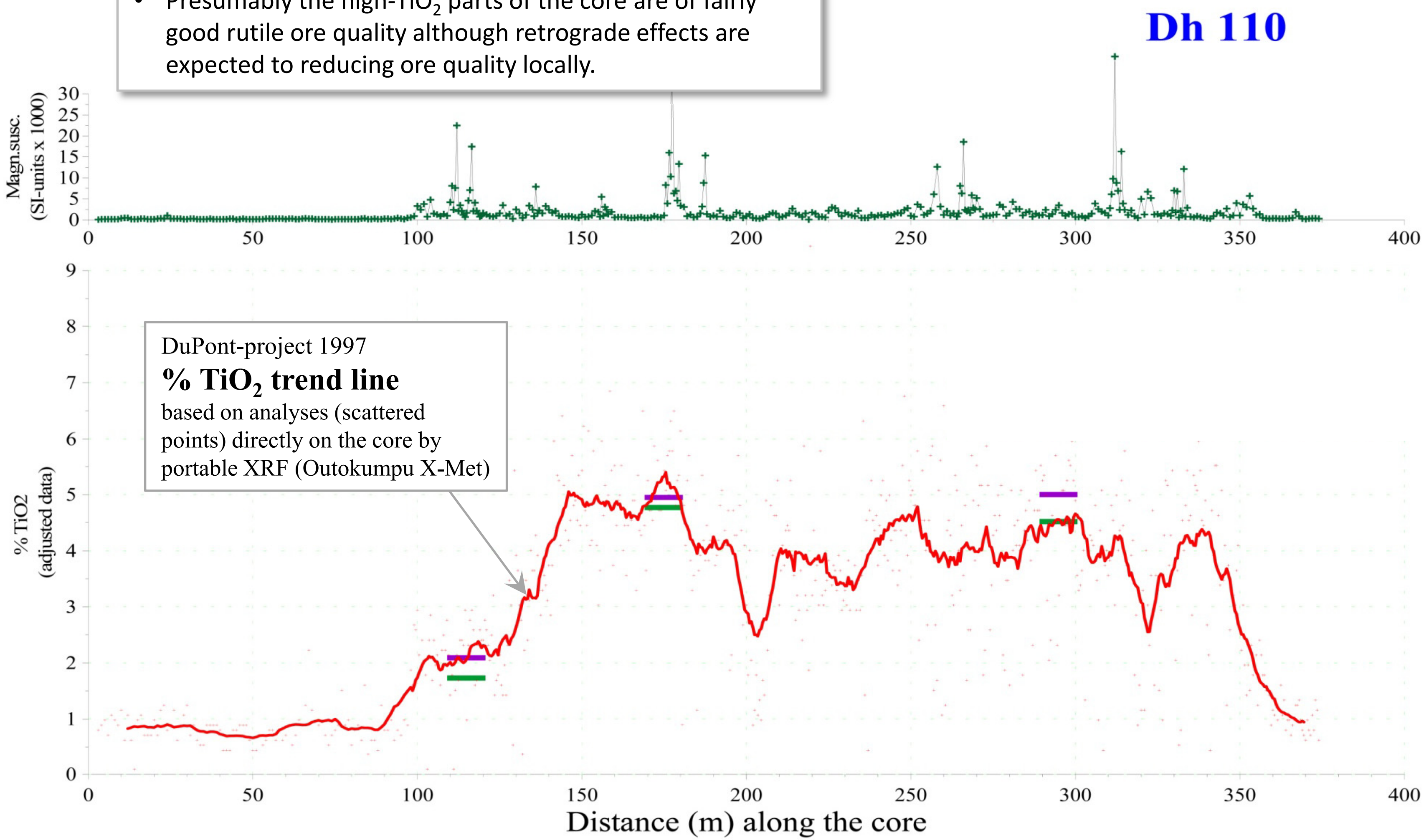
Comments Dh110

- Very distinct magnetic susceptibility in a several parts of the core indicating retrograde alteration.
- The rutile procedure analysed available show fairly high rutile/TiO_2 (see Appendix 2 and 3).
- Presumably the high-TiO_2 parts of the core are of fairly good rutile ore quality although retrograde effects are expected to reducing ore quality locally.

Engebøfjellet core information

Borehole 110

DuPont-NGU project 1995-97



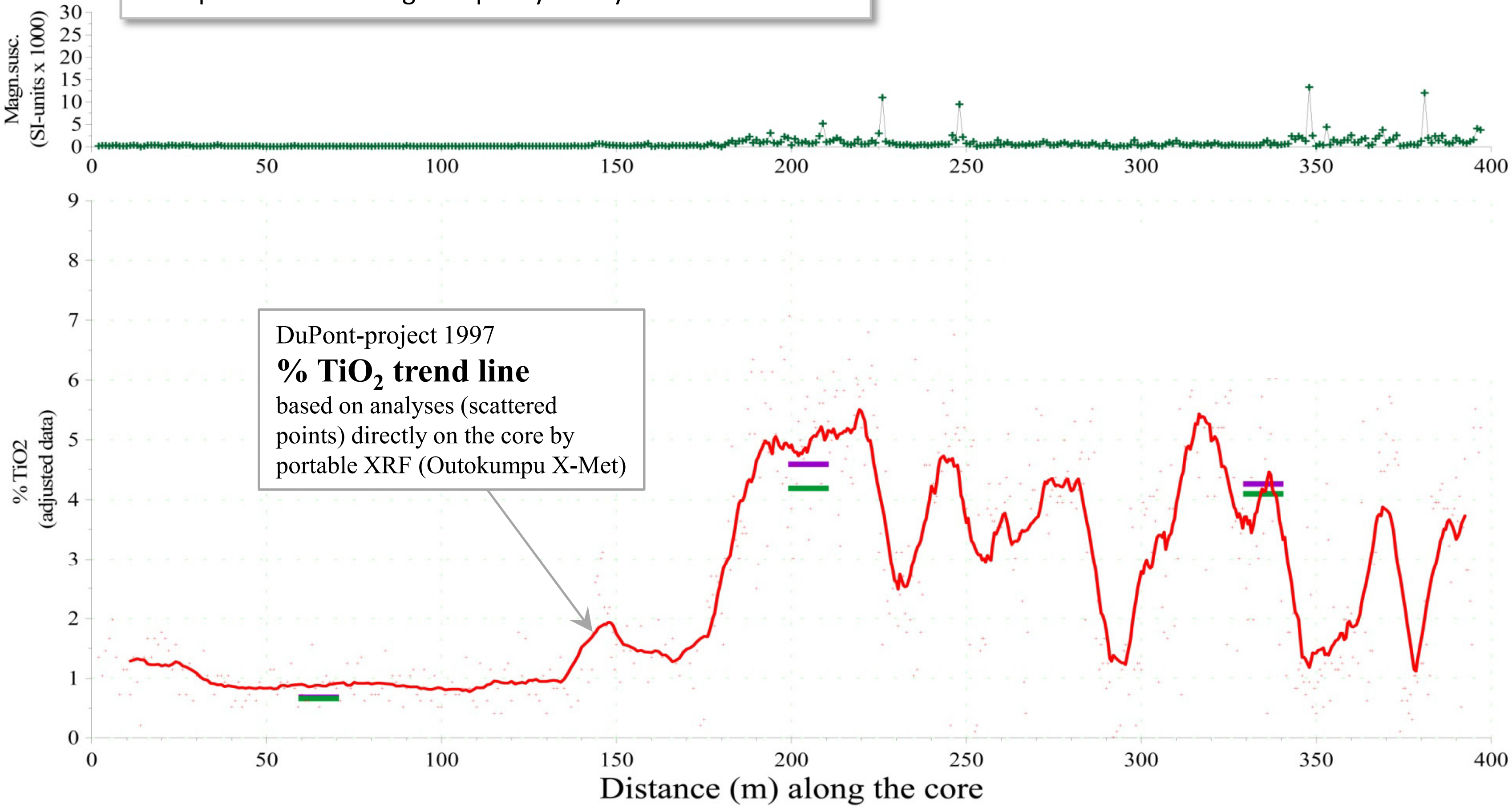
Comments Dh111

- Distinct magnetic susceptibility in a several parts of the core indicating retrograde alteration.
- The rutile procedure analysed available show fairly high rutile/TiO_2 (see Appendix 2 and 3).
- Presumably the high-TiO_2 parts of the core are of fairly good rutile ore quality although retrograde effects are expected to reducing ore quality locally.

Engebøfjellet core information

Borehole 111

DuPont-NGU project 1995-97



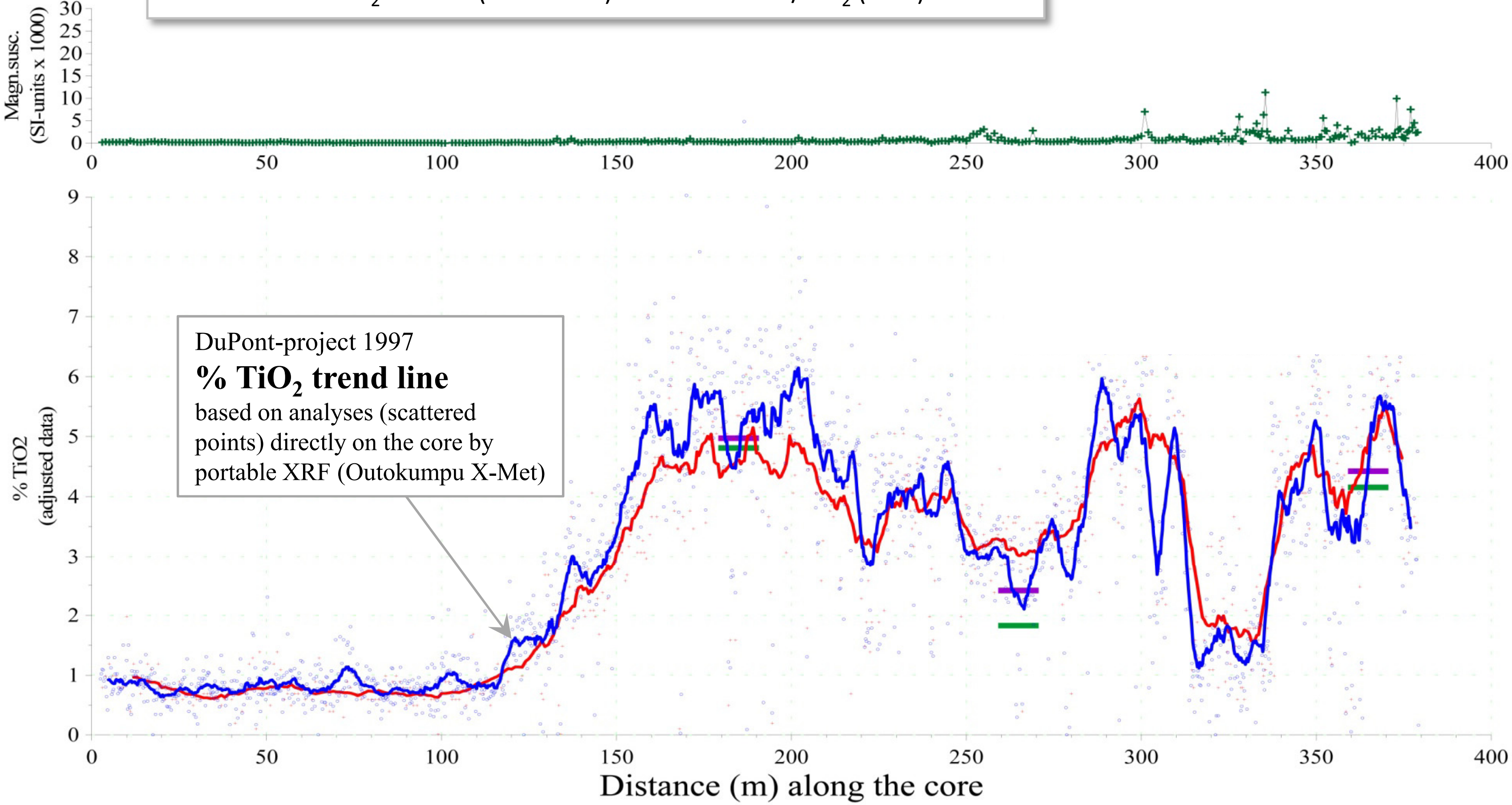
Comments Dh112

- The two trend-lines is because the core was analyses with X-Met both in the field and later at Løkken.
- Distinct magnetic susceptibility in the lower parts of the core indicating retrograde alteration.
- The rutile procedure analysed available show high rutile/TiO_2 from the TiO_2-rich parts of the core (see Appendix 2 and 3) while the sample from a low-TiO_2 section (260-270m) have low rutile/TiO_2 (0.76).

Engebøfjellet core information

Borehole 112

DuPont-NGU project 1995-97



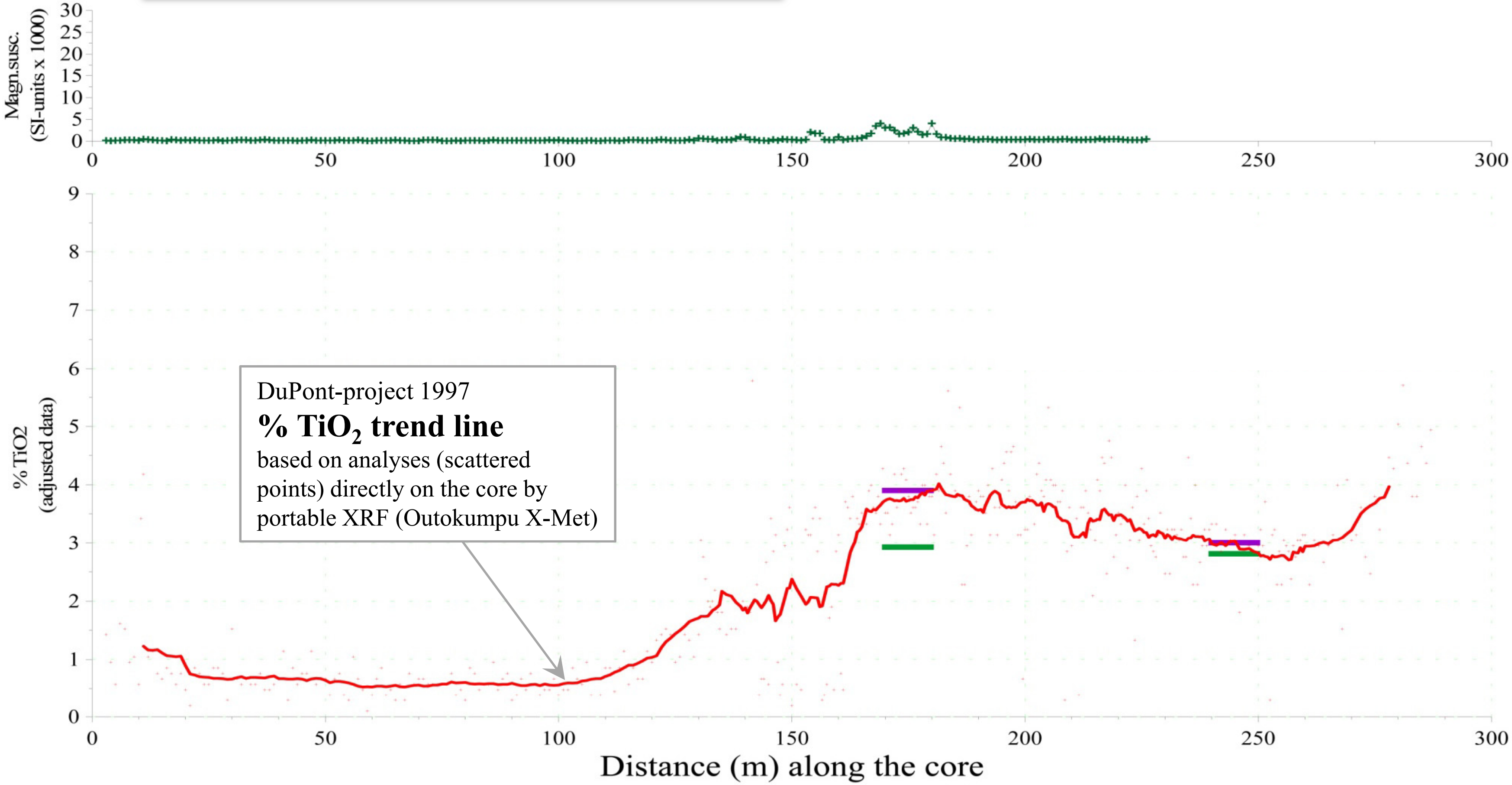
Comments Dh113

- Slightly enriched magnetic susceptibility between 150 and 170m indicating retrograde alteration.
- NB! The analysed sample from 170-180m is distinctly affected by retrograde alteration (rutile/TiO_2= 0.75) although magnetic susceptibility is not particularly high.

Engebøfjellet core information

Borehole 113

DuPont-NGU project 1995-97



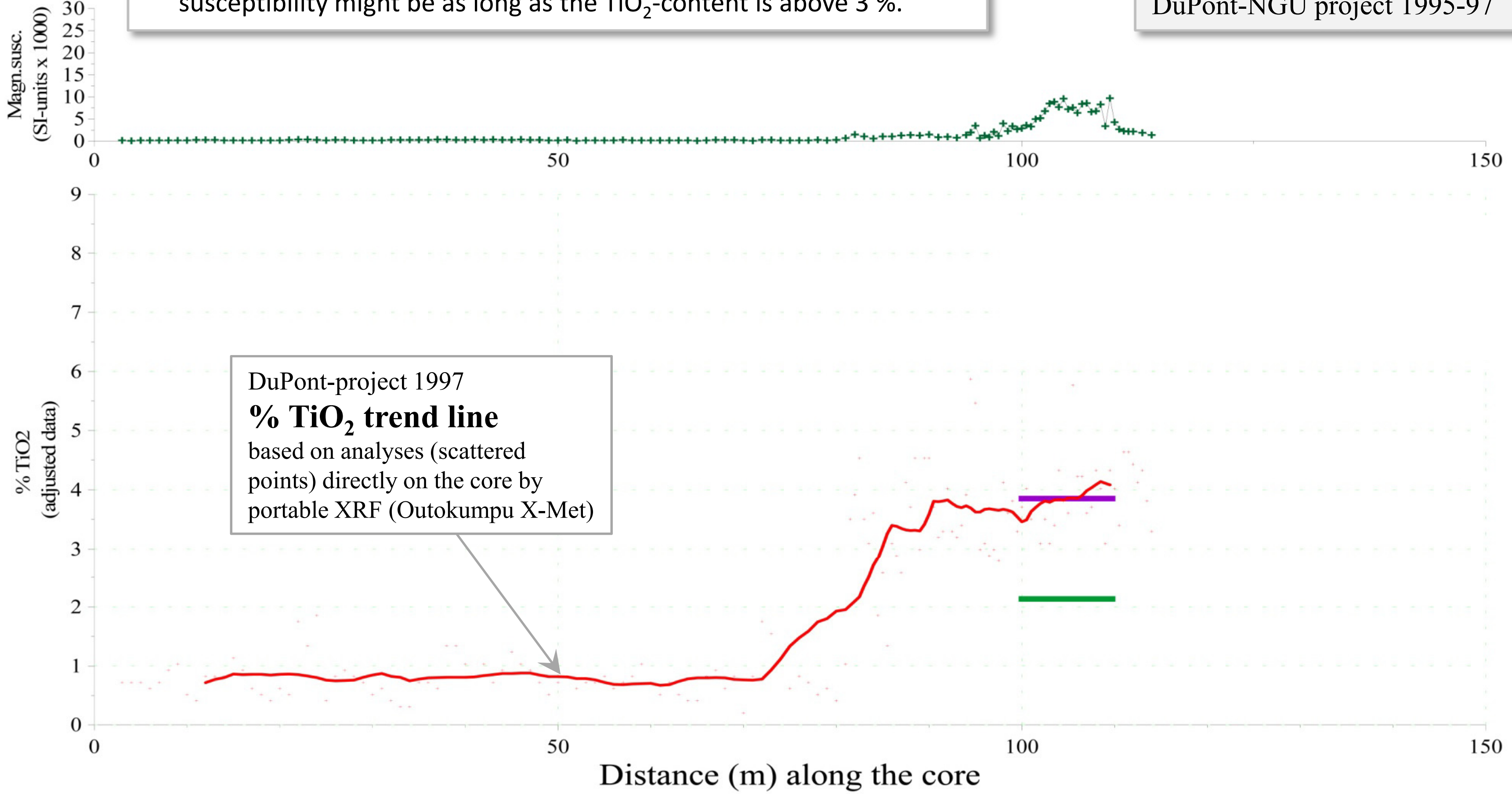
Comments Dh114

- Distinct magnetic susceptibility at 100-110m. Indicating retrograde alteration.
- The analysed sample from 100-110m is heavily affected by retrograde alteration (rutile/TiO_2= 0.55).
- The TiO_2-enriched parts of the core that has a distinct magnetic susceptibility is not of ore quality while that with low magnetic susceptibility might be as long as the TiO_2-content is above 3 %.

Engebøfjellet core information

Borehole 114

DuPont-NGU project 1995-97



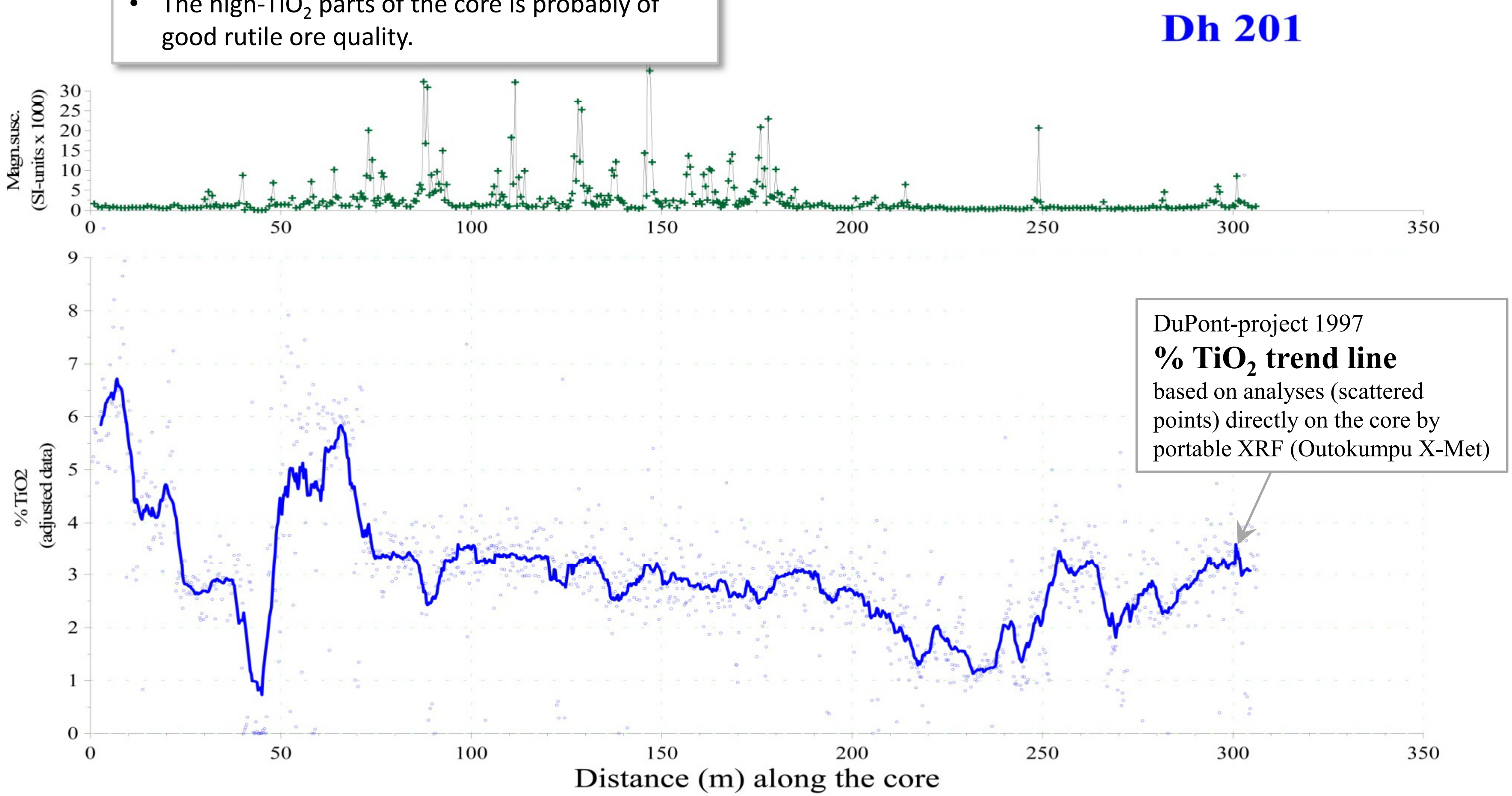
Engebøfjellet core information

Borehole 201

DuPont-NGU project 1995-97

Comments Dh201

- Distinct to high magnetic susceptibility in some parts of the core, indicating extensive retrograde alteration.
- No rutile analyses are available.
- The high-TiO_2 parts of the core is probably of good rutile ore quality.



Comments Dh202

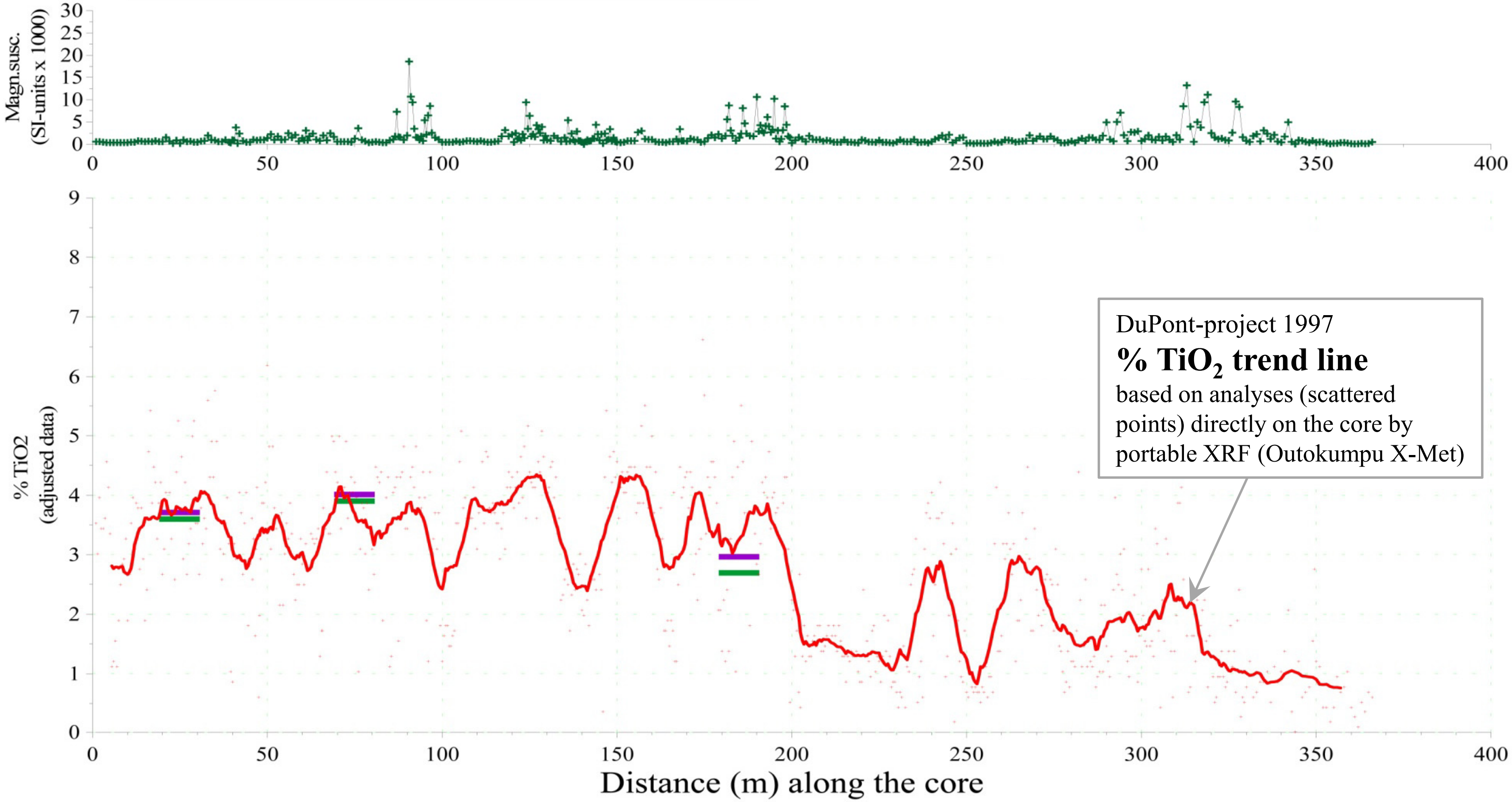
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably good rutile ore.

Engebøfjellet core information

Borehole 202

DuPont-NGU project 1995-97

Dh 202



Comments Dh203

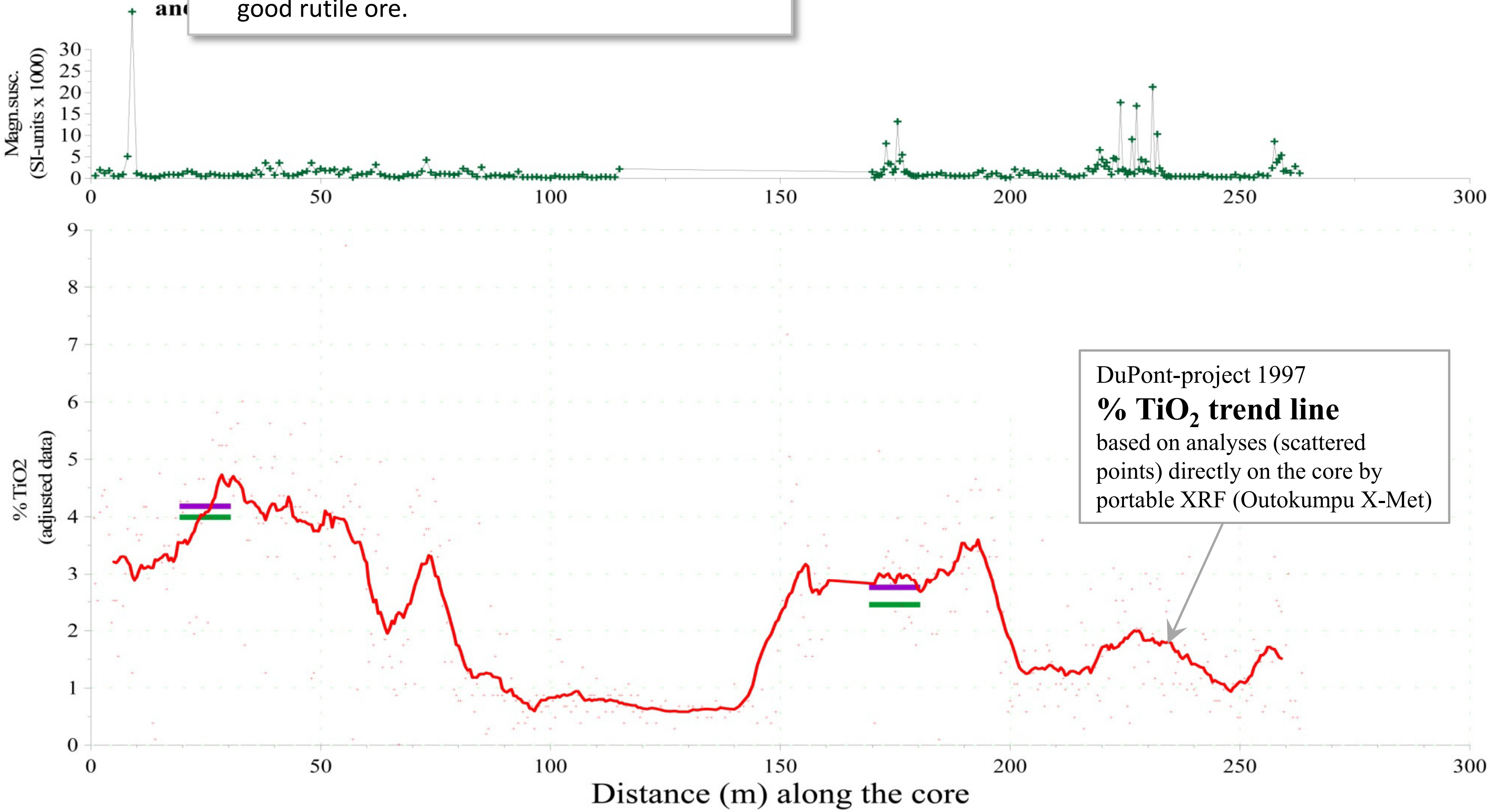
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably good rutile ore.

Engebøfjellet core information

Borehole 203

DuPont-NGU project 1995-97

Dh 203



Comments Dh204

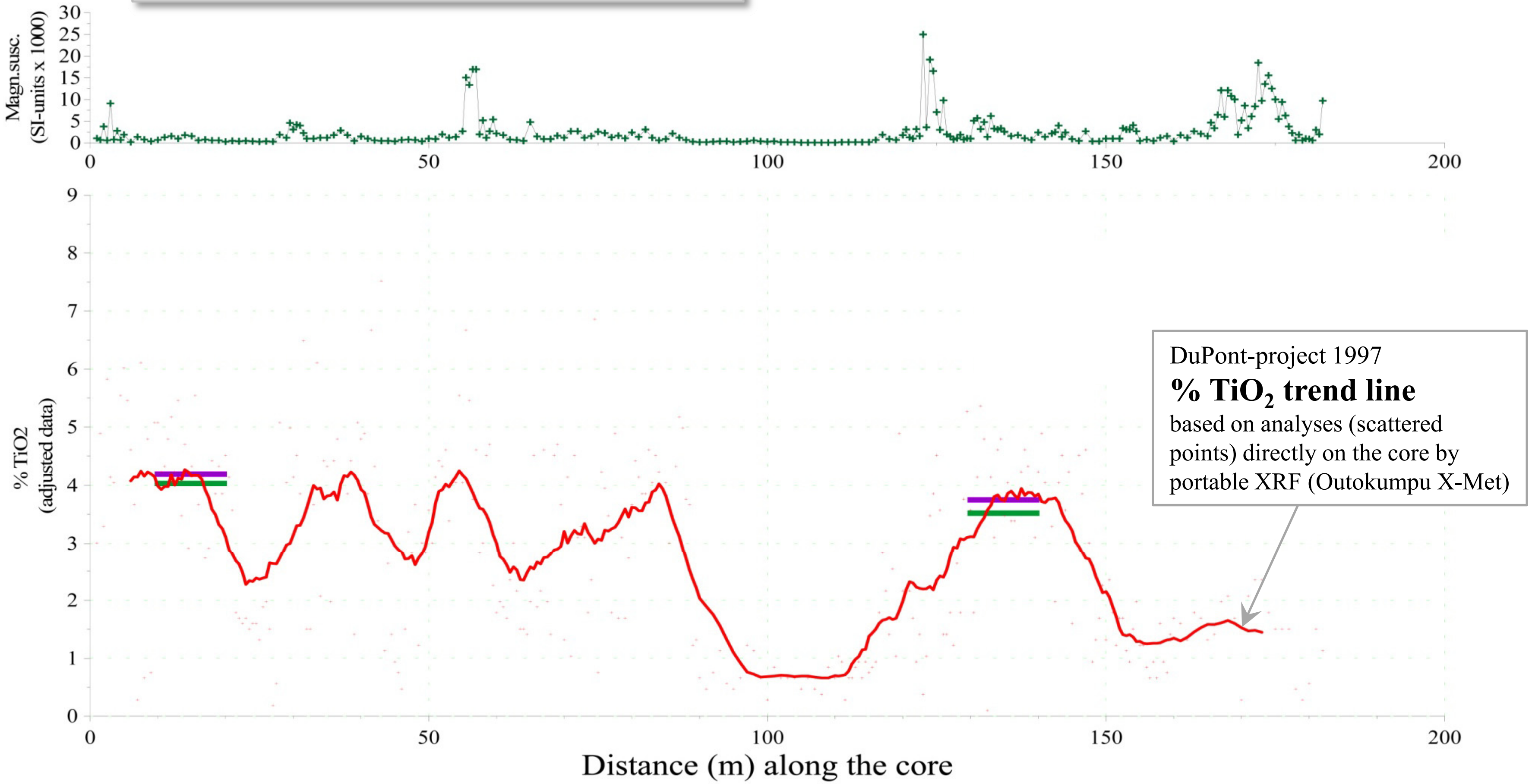
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably good rutile ore.

Engebøfjellet core information

Borehole 204

DuPont-NGU project 1995-97

Dh 204



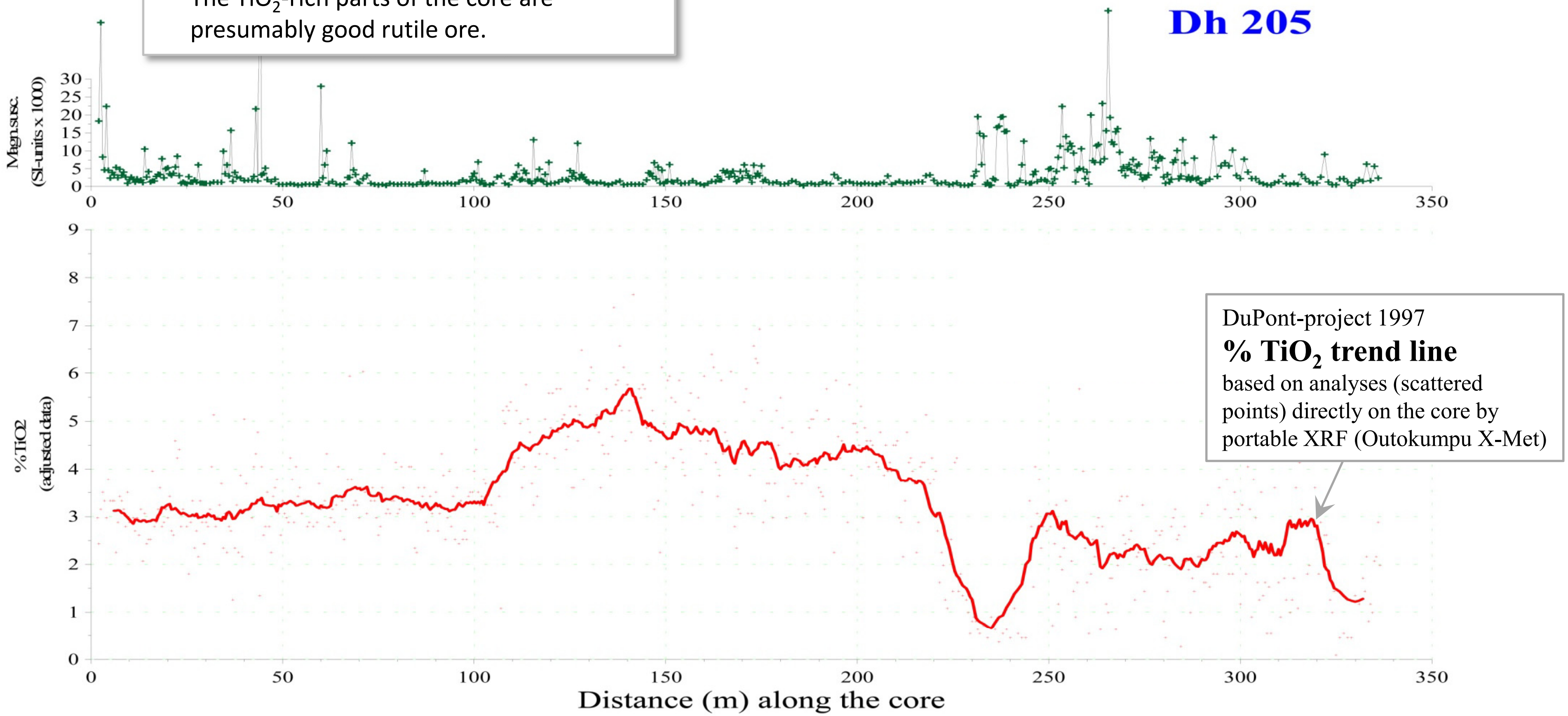
Comments Dh205

- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- No rutile analyses are available.
- The TiO_2-rich parts of the core are presumably good rutile ore.

Engebøfjellet core information

Borehole 205

DuPont-NGU project 1995-97



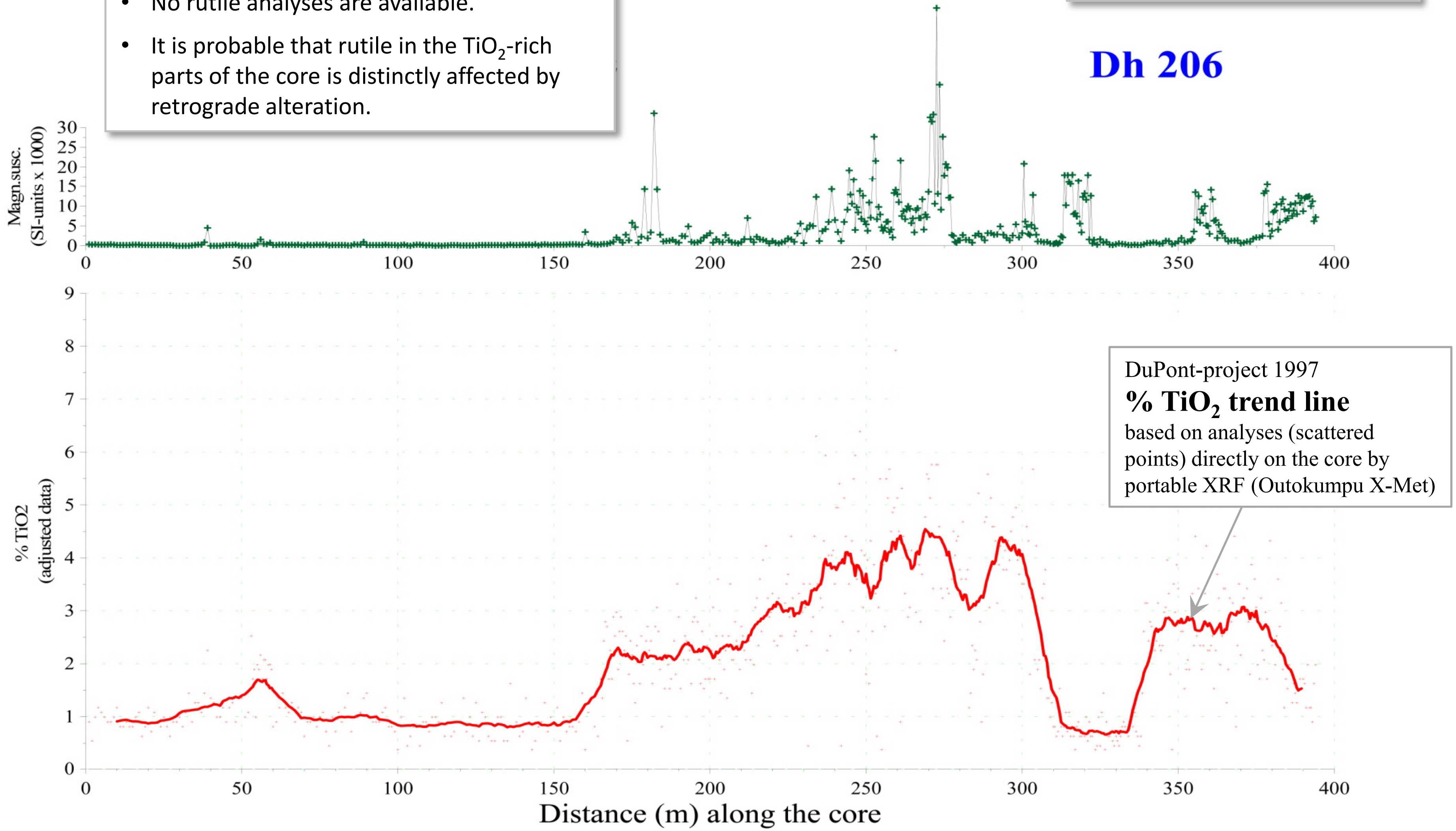
Comments Dh206

- Distinct to very strong magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- No rutile analyses are available.
- It is probable that rutile in the TiO_2-rich parts of the core is distinctly affected by retrograde alteration.

Engebøfjellet core information

Borehole 206

DuPont-NGU project 1995-97



Comments Dh207

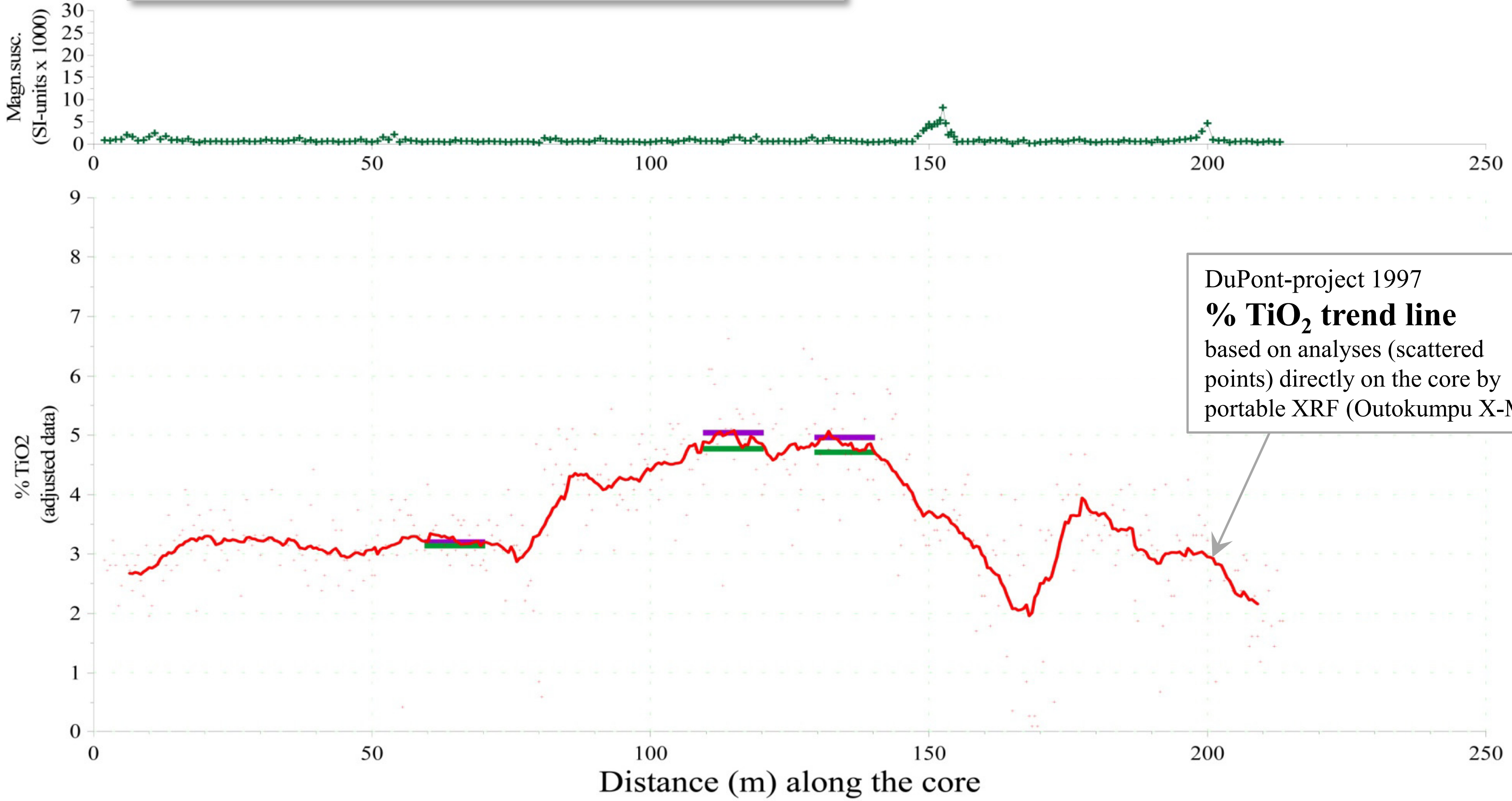
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are of good rutile ore quality.

Engebøfjellet core information

Borehole 207

DuPont-NGU project 1995-97

Dh 207



Comments Dh208

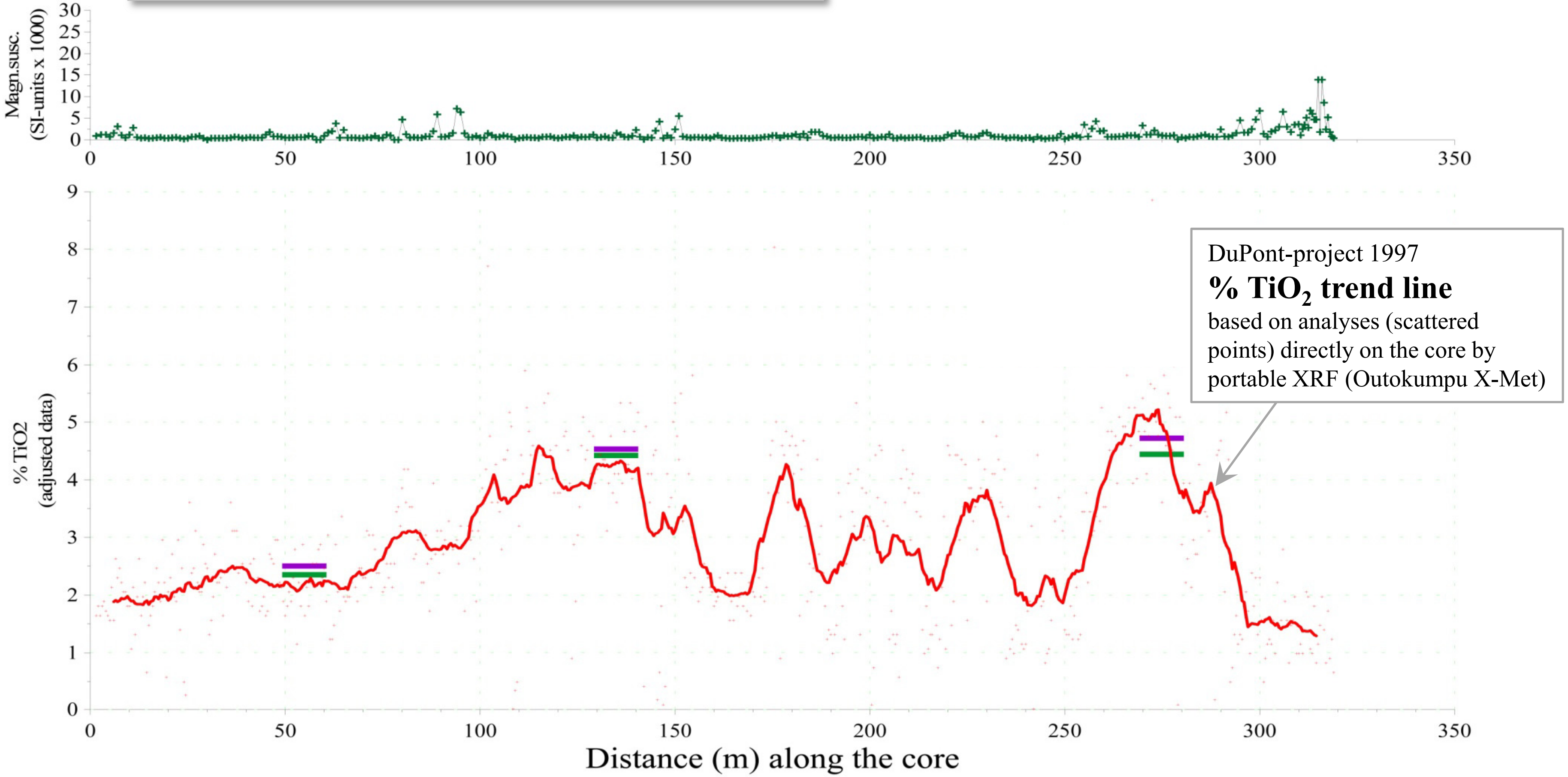
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are of good rutile ore quality.

Engebøfjellet core information

Borehole 208

DuPont-NGU project 1995-97

Dh 208



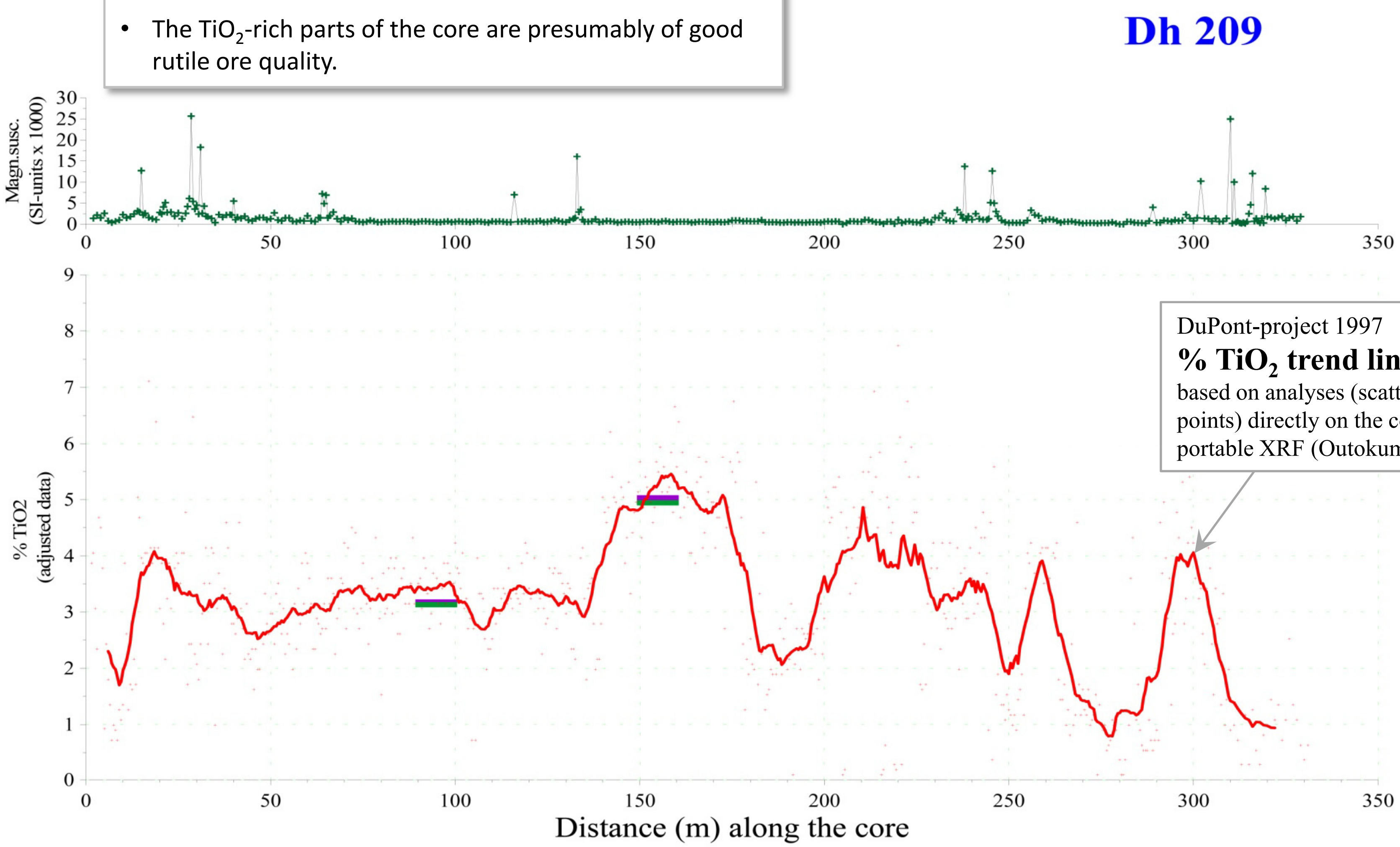
Comments Dh209

- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Engebøfjellet core information

Borehole 209

DuPont-NGU project 1995-97



Comments Dh210

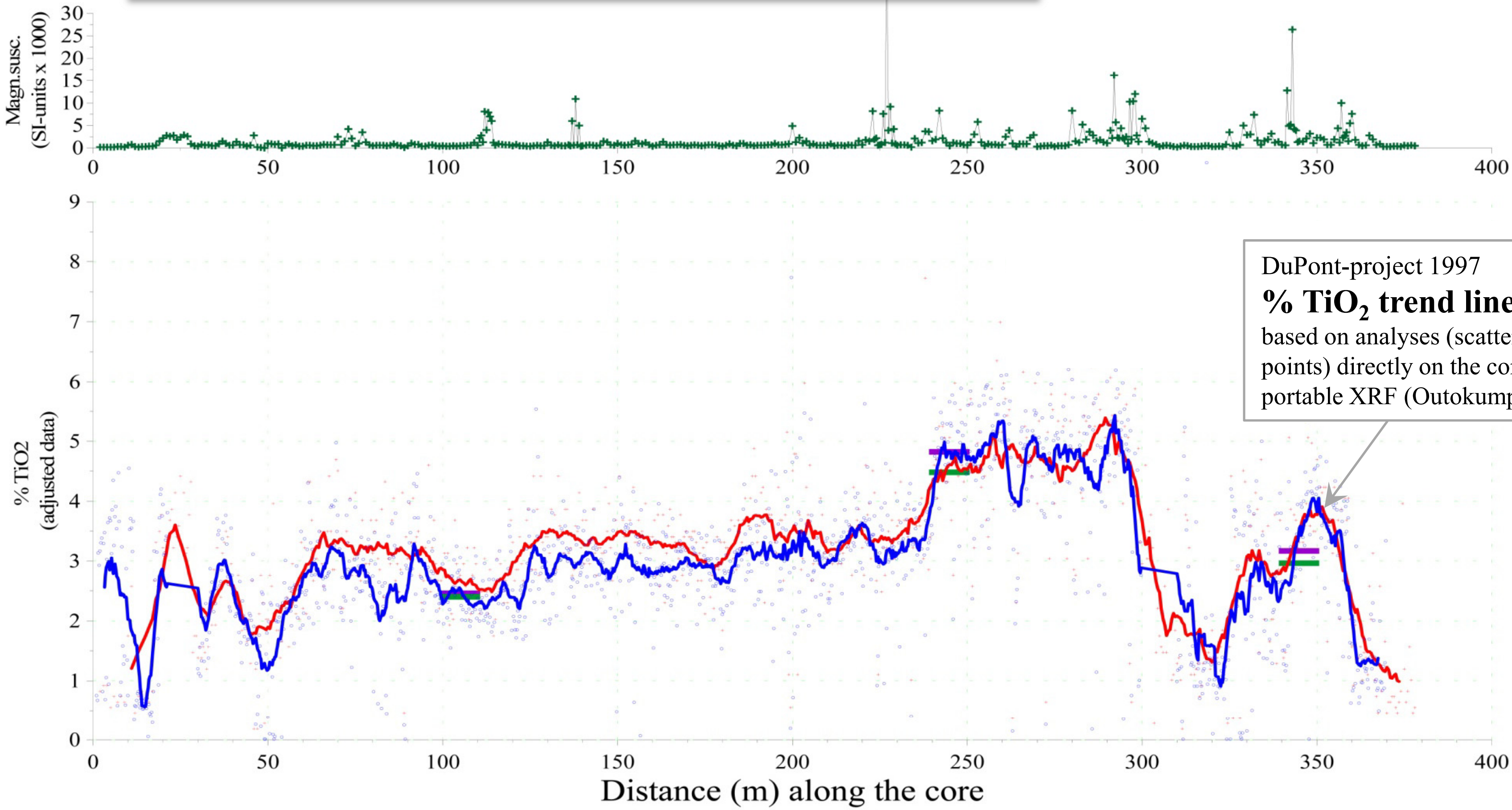
- The two trend-lines is because the core was analyses with X-Met both in the field and later at Løkken.
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Engebøfjellet core information

Borehole 210

DuPont-NGU project 1995-97

Dh 210



Comments Dh211

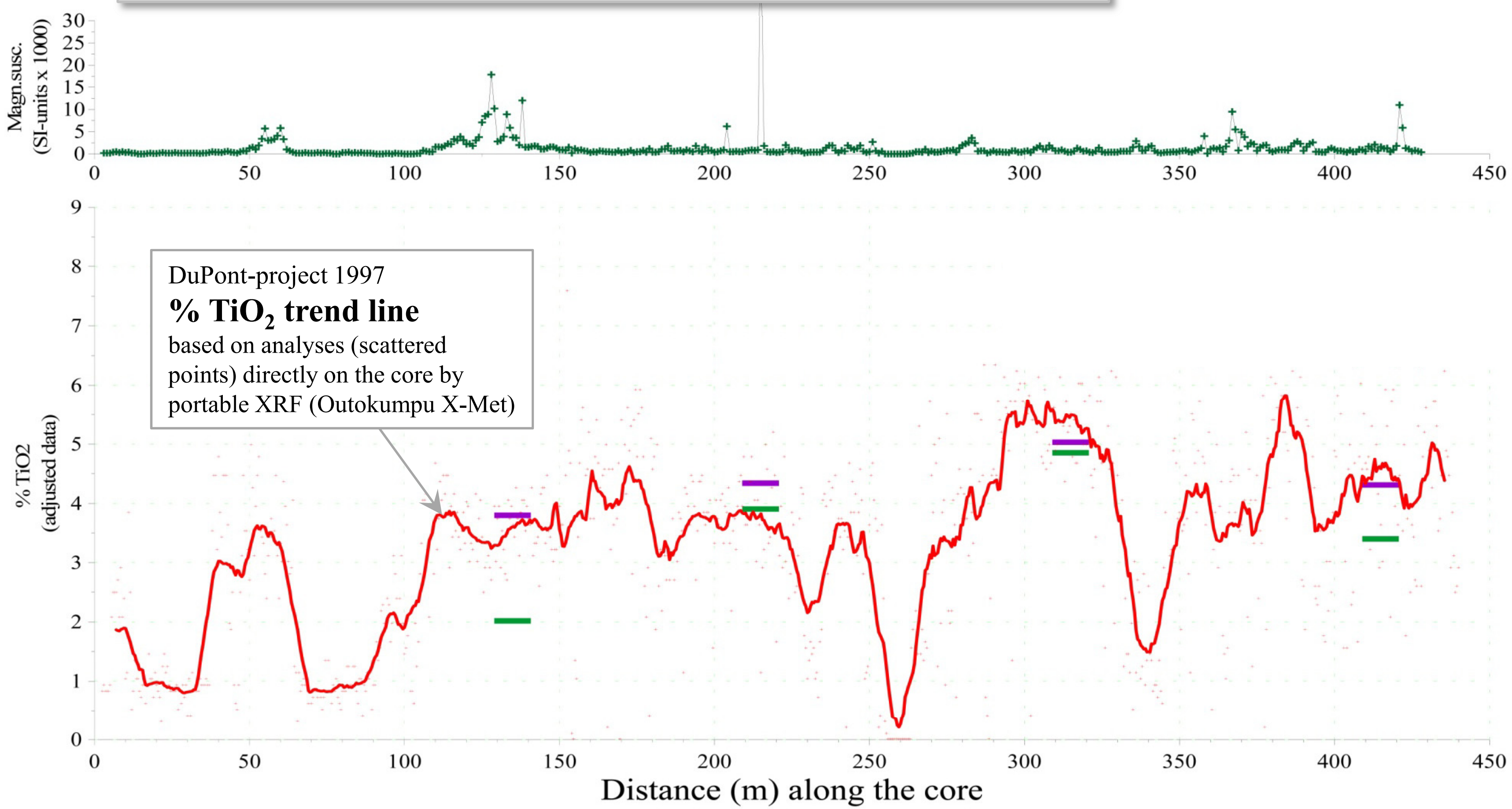
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show variable rutile/TiO_2-ratios (see Appendix 2 and 3).
- Most of the TiO_2-rich parts of the core are presumably of good rutile ore quality. However, distinct effects on rutile ore quality is indicated by reduced rutile/TiO_2-ratios in the analysed core sections 130-140m and 410-420m.

Engebøfjellet core information

Borehole 211

DuPont-NGU project 1995-97

Dh 211



Comments Dh212

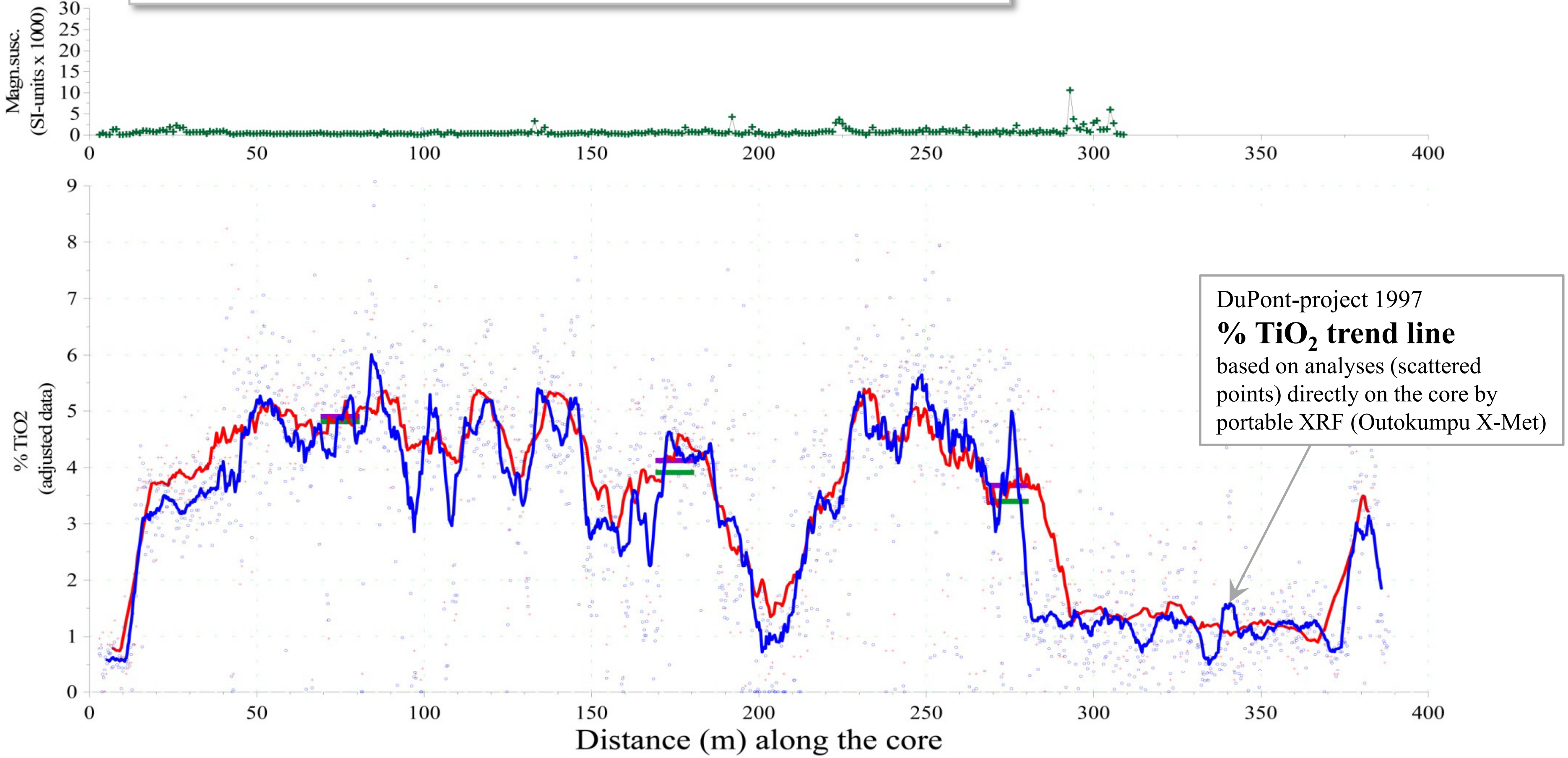
- The two trend-lines is because the core was analyses with X-Met both in the field and later at Løkken.
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Engebøfjellet core information

Borehole 212

DuPont-NGU project 1995-97

Dh 212



Comments Dh213

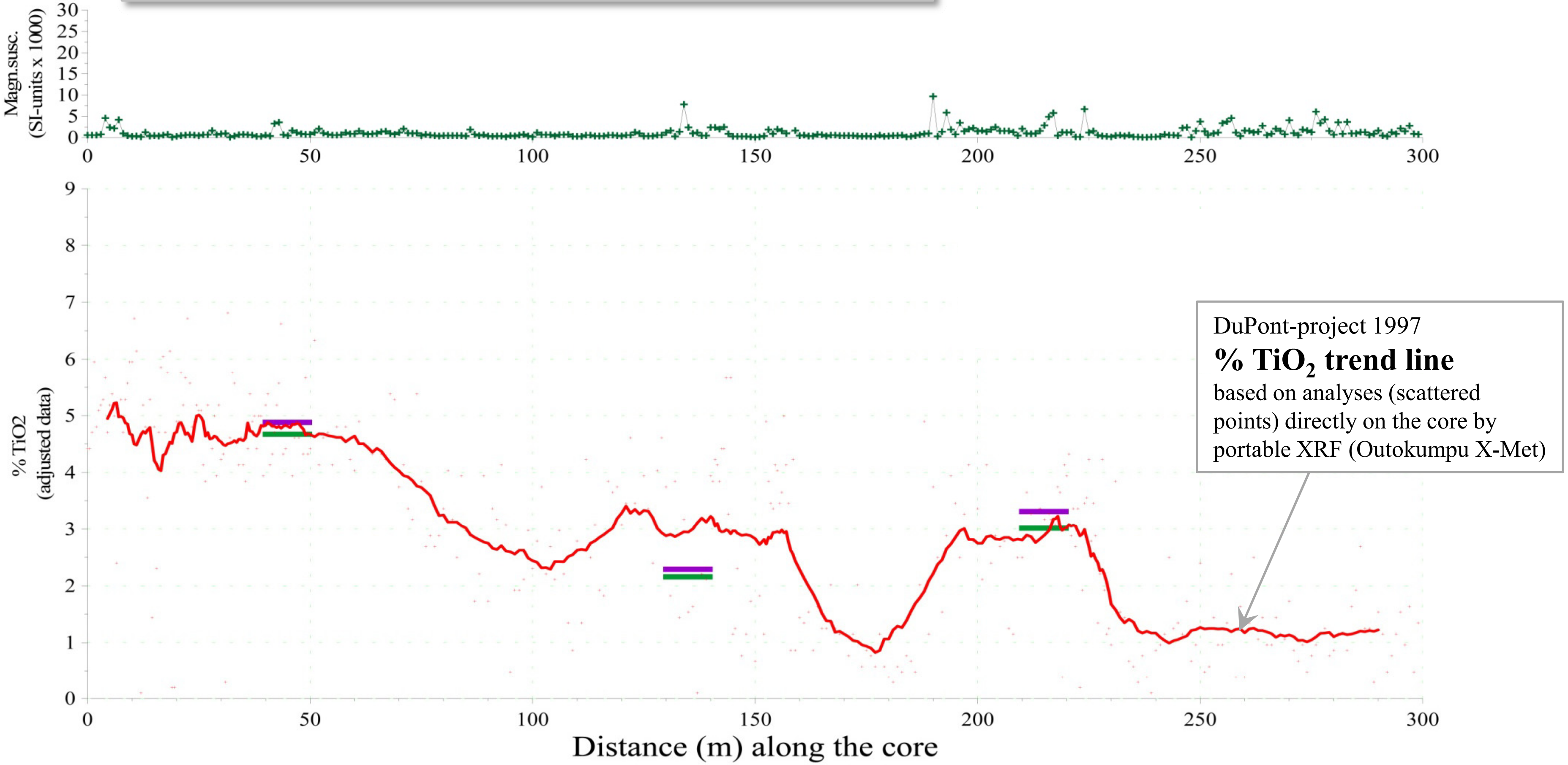
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Engebøfjellet core information

Borehole 213

DuPont-NGU project 1995-97

Dh 213



Comments Dh214

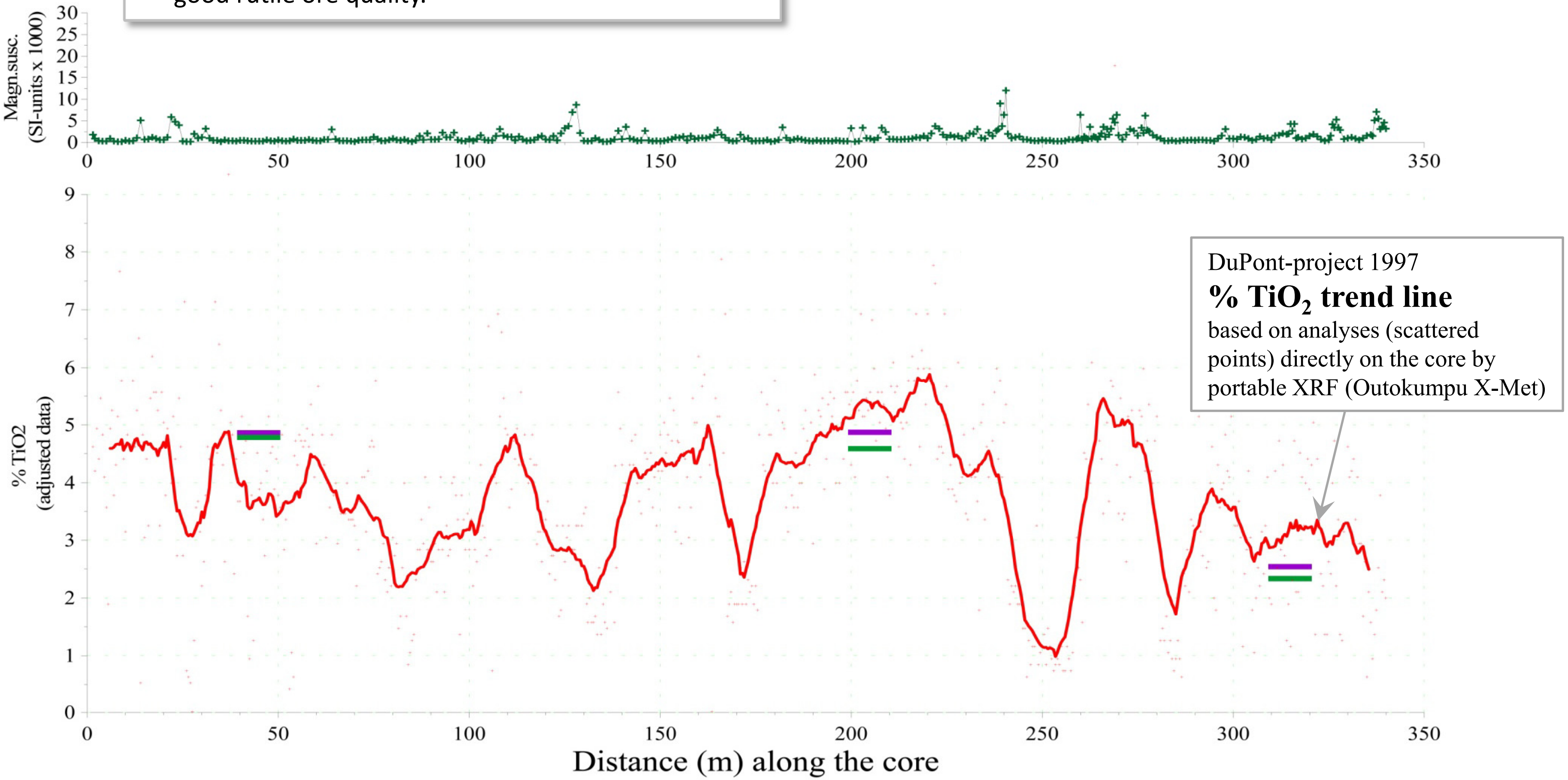
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Engebøfjellet core information

Borehole 214

DuPont-NGU project 1995-97

Dh 214



Engebøfjellet core information

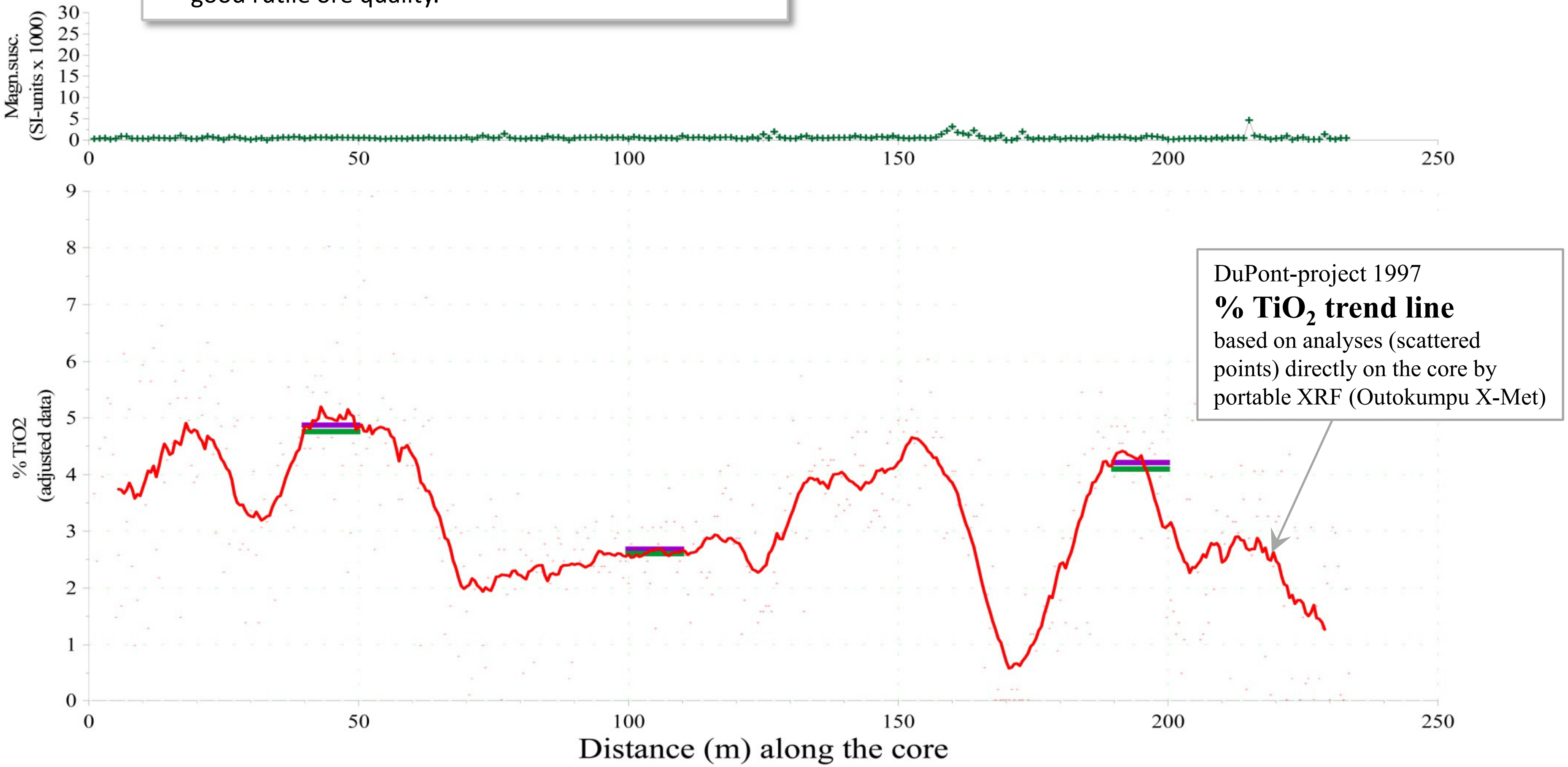
Borehole 301

DuPont-NGU project 1995-97

Comments Dh301

- Weak magnetic susceptibility in some parts of the core, indicating some retrograde alteration.
- Rutile analyses show very high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Dh 301



Comments Dh302

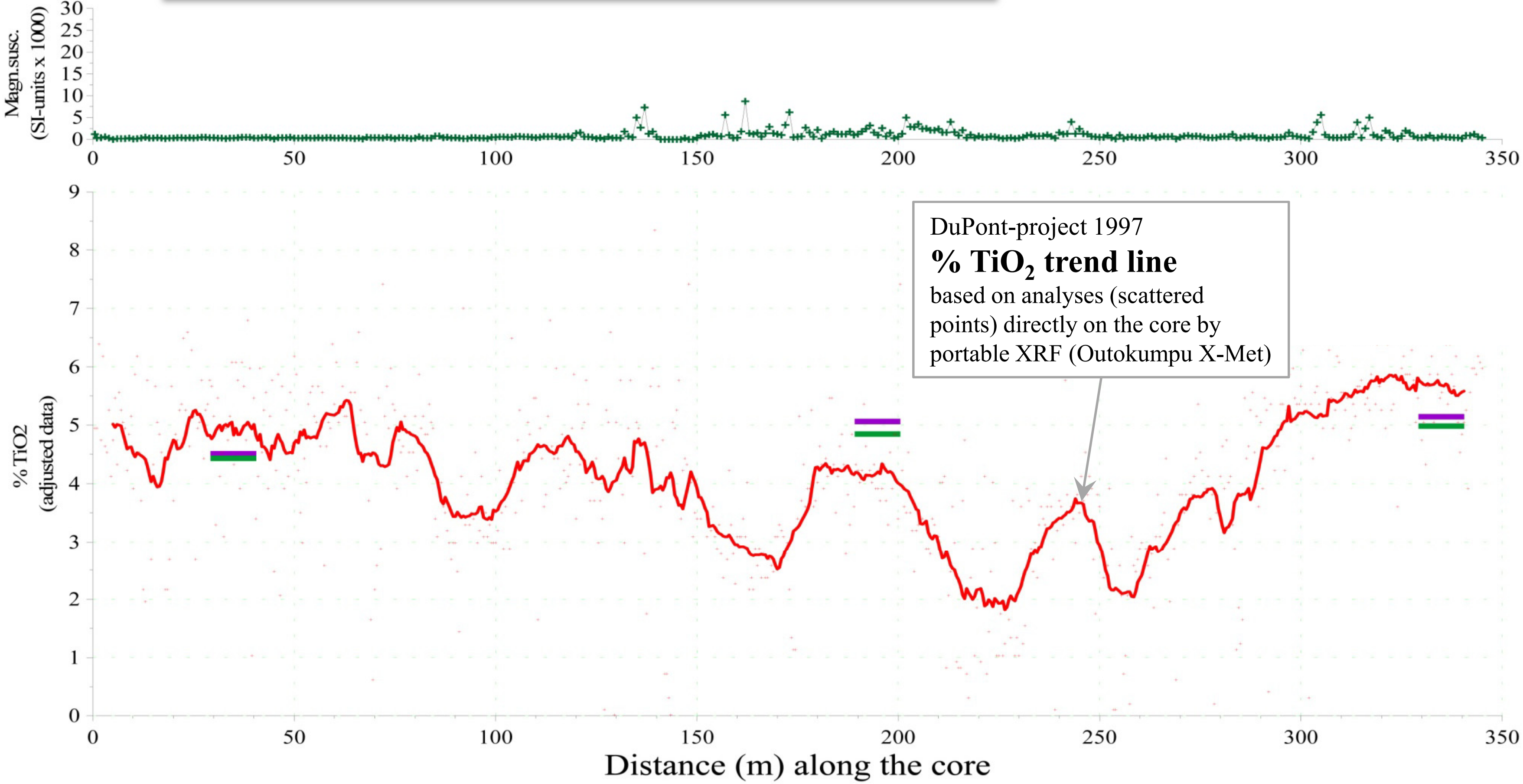
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Engebøfjellet core information

Borehole 302

DuPont-NGU project 1995-97

Dh 302



Comments Dh303

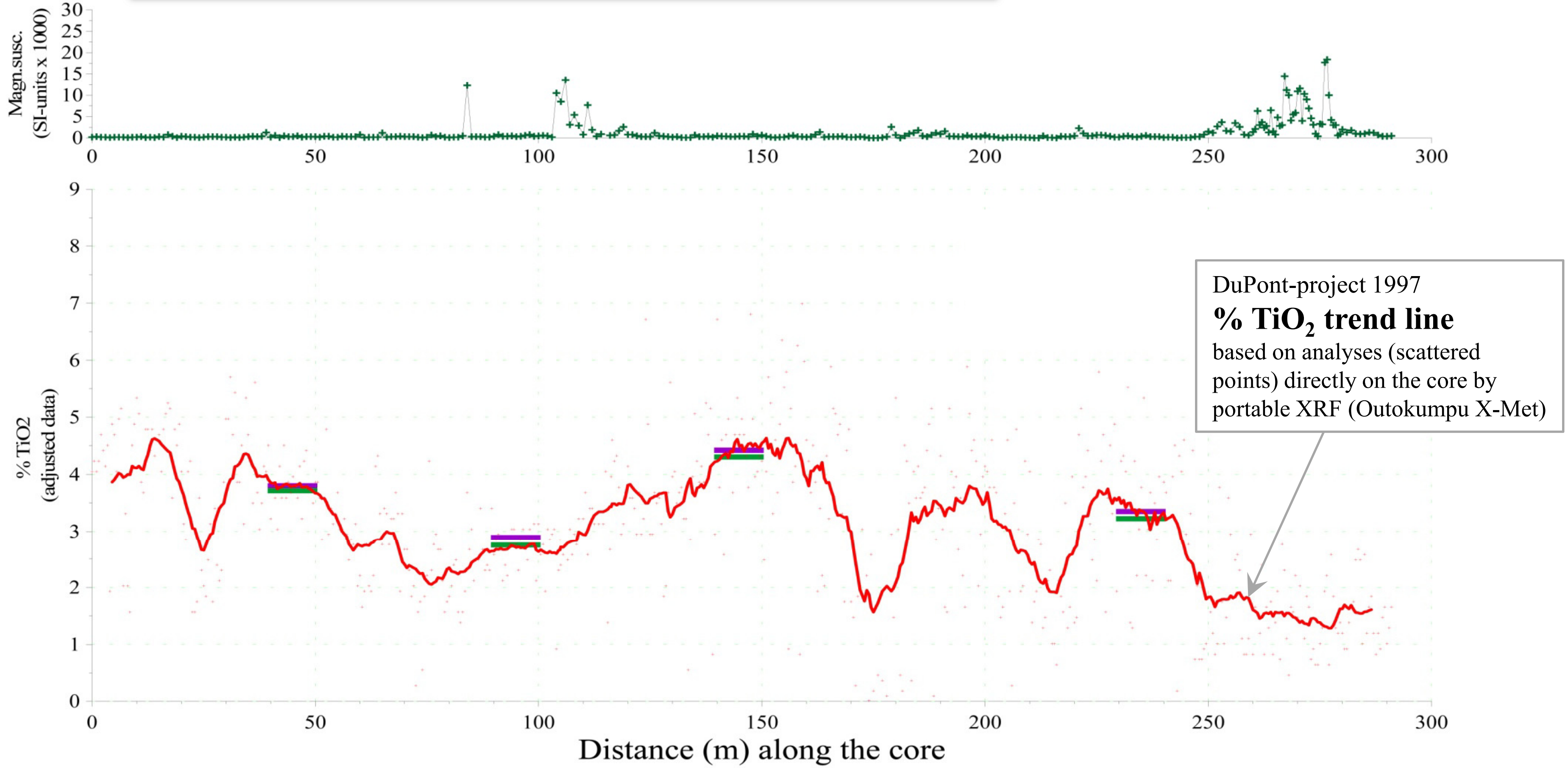
- Distinct magnetic susceptibility in some parts of the core, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3), although not from sections with high magnetic susceptibility.
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Engebøfjellet core information

Borehole 303

DuPont-NGU project 1995-97

Dh 303



Comments Dh304

- Distinct magnetic susceptibility in some parts of the core, particularly in the lower parts, indicating retrograde alteration.
- Rutile analyses show high rutile/TiO_2-ratios (see Appendix 2 and 3).
- The TiO_2-rich parts of the core are presumably of good rutile ore quality.

Engebøfjellet core information

Borehole 304

DuPont-NGU project 1995-97