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Rutile-bearing rocks in the outer Sognefjord region, W. Norway

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REPORT

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Title:
Rutile-bearing rocks in the outer Sognefjord region, W. Norway

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Deposit name and grid-reference: Hellebøheia (307200/6777400), Slengesol (292700/6761730), Norddal (292700/6762550), Kjelbju (296800/6762900) and Veten (277500/6757200)	Number of pages: 22 Price (NOK): - Map enclosures: 0

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Summary:

In previous investigations of rutile-bearing eclogites in western Norway, only minor attention was given to the Outer Sognefjord (incl. Gulen) region, even though it was well known that rutile-bearing eclogites occur in the region. The purpose of the present investigation is to evaluate the rutile potential of this region, based on previous investigation and some additional field work.

In general, mafic rocks in the eastern parts of the region, particularly on the south side of Sognefjord, have experienced very incomplete eclogitisation, commonly in distinct association with shear zones. In such cases, only a portion (20 to 60% or so) of the titanium in the rock will occur as rutile, at least if one considers deposits of significant size. In the western part of the region eclogitisation of mafic rocks seems to have been relatively complete, although in most examples observed in the field, eclogites have been significantly retrograded to amphibolite. In the amphibolitised eclogites, rutile is partly or fully altered to ilmenite and in some cases also to titanite.

The TiO_2-content in the mafic rocks (metagabbro, eclogite, amphibolite) found in the area is generally 2-3 % TiO_2 although 3-4 % TiO_2 does occur within eclogites such as Veten at Byrknesøy, Hellebøheia near Lavik, and Slengesol, Nordal and Kjelbju in the Dalsfjell area.

The present observations do not give any reason for optimism regarding rutile deposits of great economic interest.

Keywords: Mineral resource	Titanium	Rutile
Eclogite		

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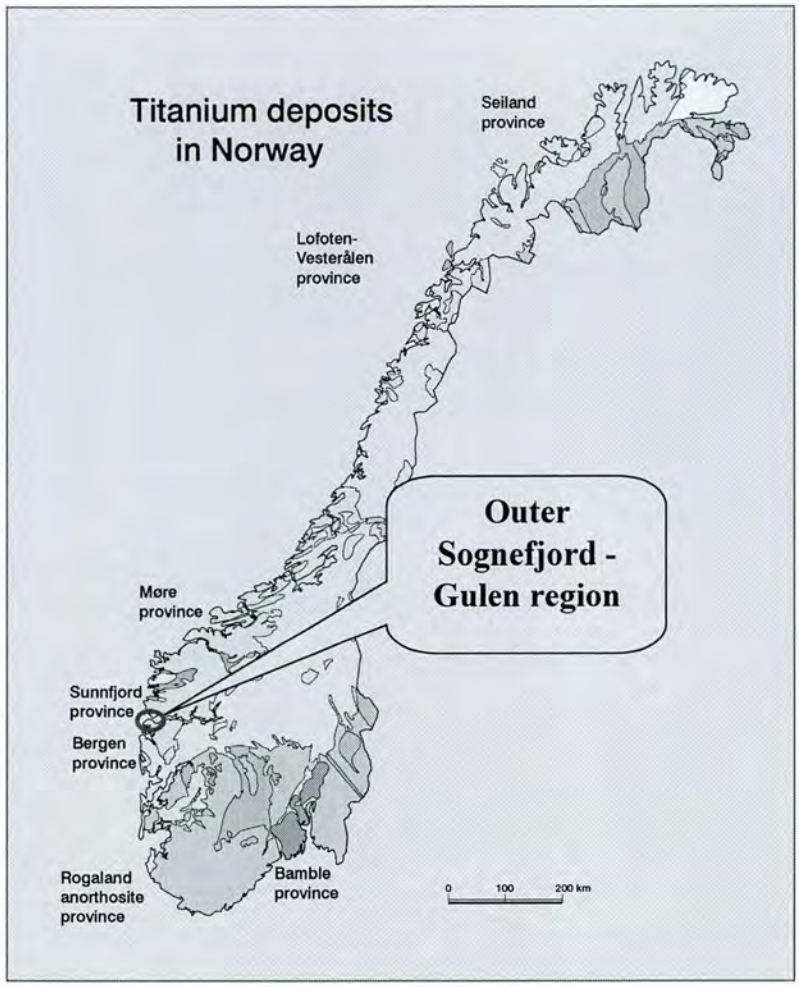


Fig. 1: Location map, Outer Sognefjord - Gulen region.

1. INTRODUCTION

In previous investigations of rutile-bearing eclogites in western Norway, only minor attention was given to the Outer Sognefjord (incl. Gulen) region, although it is well known that rutile-bearing eclogites occur in the region. The purpose of the present investigation is to evaluate the rutile potential in this region based on previous investigations and some additional field work.

2. ECLOGITES ON THE NORTHERN SIDE OF SOGNEFJORD

The only significant eclogite known on the northern side of Sognefjord is the Hellebøheia eclogite west of Lavik (Fig. 2), approximately 500 meters above sea level and only 1 km from the fjord. Some reconnaissance X-Met field analyses were done in 1995 within the NGU-DuPont project. However, this information was neither properly reported nor followed up, due to the focus on Engebøfjellet eclogite at Førdefjord later the same year. The size of the eclogite is roughly as indicated on map (1) in Fig. 2. The eclogite is distinctly folded and generally dips northwards. The rutile is distinctly retrograded to ilmenite, although no precise

data are available to quantify this. The rutile grain size is "acceptable", i.e. distinctly larger than at the Engebøfjellet eclogite (see Korneliussen et al. 1999). The field impression in 1995 was that the deposit is probably too small to be of economic interest, considering that the TiO_2 grade is in the range 2-4 %, but there might be an ore potential at depth.

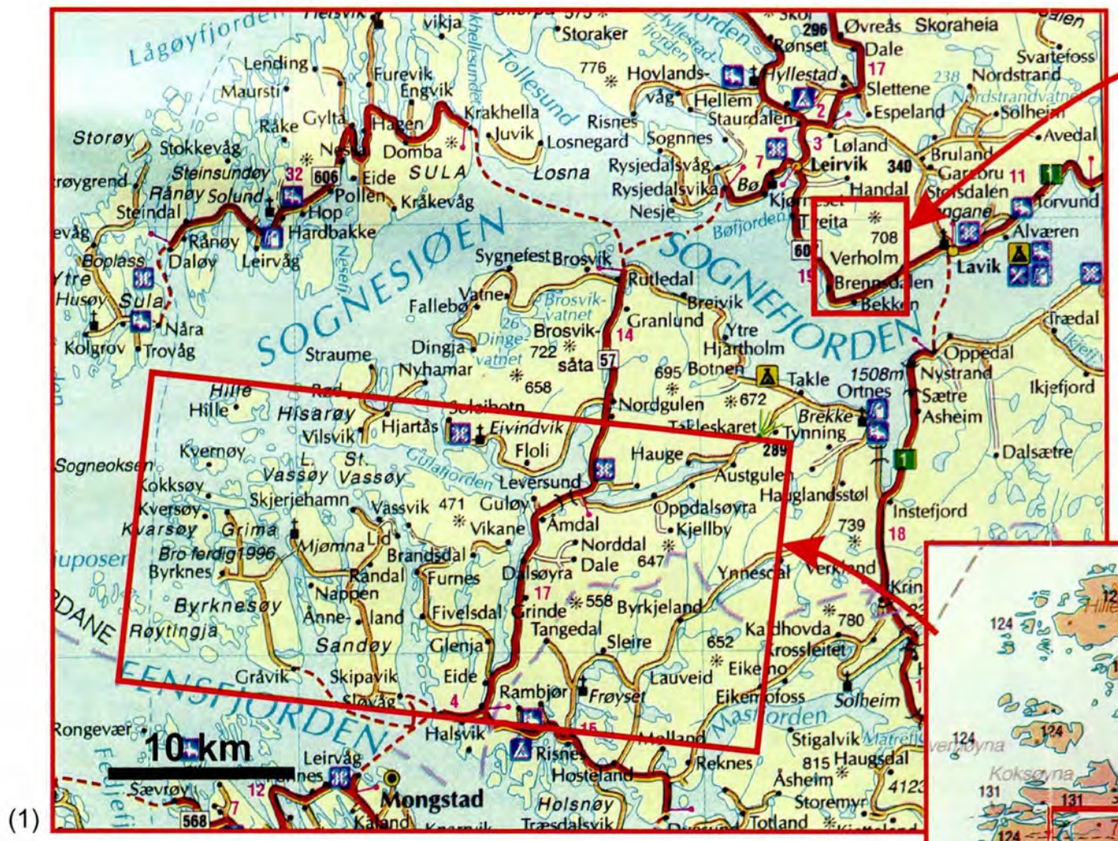
Microphotographs of thin sections of 3 samples from the Hellebøheia eclogite are shown in Figures 3, 4 and 5. All these samples are distinctly retrograded. The omphacitic clinopyroxene is significantly altered to fine-grained aggregates of plagioclase and amphibole, and a large proportion of the rutile is altered to ilmenite in all three samples, now seen as ilmenite intergrown with rutile. In sample 394.02 titanite has been formed at the rim of some large rutile/ilmenite grains.

The overall impression is that less than 50% of the titanium in the eclogite occurs as rutile. Consequently, the rutile content in this eclogite is approximately 2% or lower, and further investigations in this area are not recommended.

Table 1: X-Met analyses, Hellebøheia eclogite, Lavik.

	Sample 394,01		Sample 394,04		Sample 394,05		Sample 394,02		Sample 394,03	
	TiO_2	Fe_2O_3	TiO_2	Fe_2O_3	TiO_2	Fe_2O_3	TiO_2	Fe_2O_3	TiO_2	Fe_2O_3
	6.4	17.5	2.9	15.6	2.1	13.7	2.2	14.1	2.0	14.7
	2.4	13.5	2.4	14.6	2.9	15.4	2.0	15.3	2.3	14.1
	2.9	15.9	2.5	14.2	2.4	13.8	5.9	16.7	3.2	14.0
	4.3	18.9	2.2	13.6	2.8	12.7	3.1	14.7	2.0	13.7
	7.6	19.3	2.9	15.6	3.2	17.1	3.3	15.7	2.0	14.4
	5.7	16.7	1.8	12.5			3.0	16.5	0.8	9.9
	2.9	15.0							1.1	13.8
	4.7	19.8							4.3	15.2
	8.9	18.2							3.9	19.4
									1.6	13.7
Avg.:	5.1	17.2	2.5	14.5	2.7	14.5	3.3	15.5	2.3	14.3

Overview
Sognefjord-Gulen



(1) (2) (3)

Fig. 2: Maps, Outer Sognefjord-Gulen region, W. Norway. (1): Overview road map of Outer Sognefjord-Gulen region. (2): Topographic map of the Hellebøheia area on the northern side of Sognefjord. (3): Overview geological map of the Dalsfjell - Byrknesøy area south of Sognefjord. This map is a part of the 1:250 000 scale geological map Bergen (Ragnhilstveit & Helliksen 1997).

Fig. 4

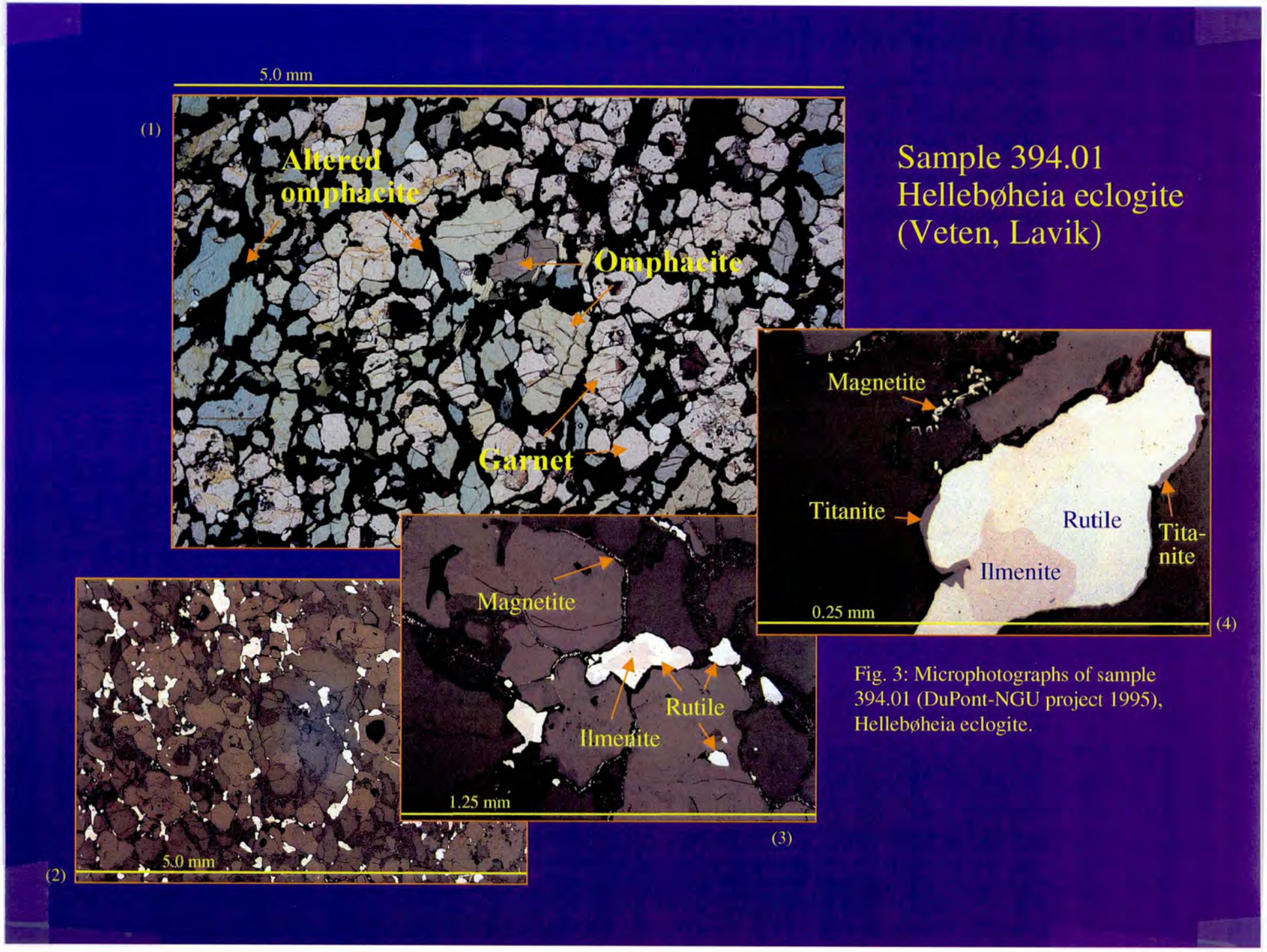


Fig. 3: Microphotographs of sample 394.01 (DuPont-NGU project 1995), Hellebøheia eclogite.

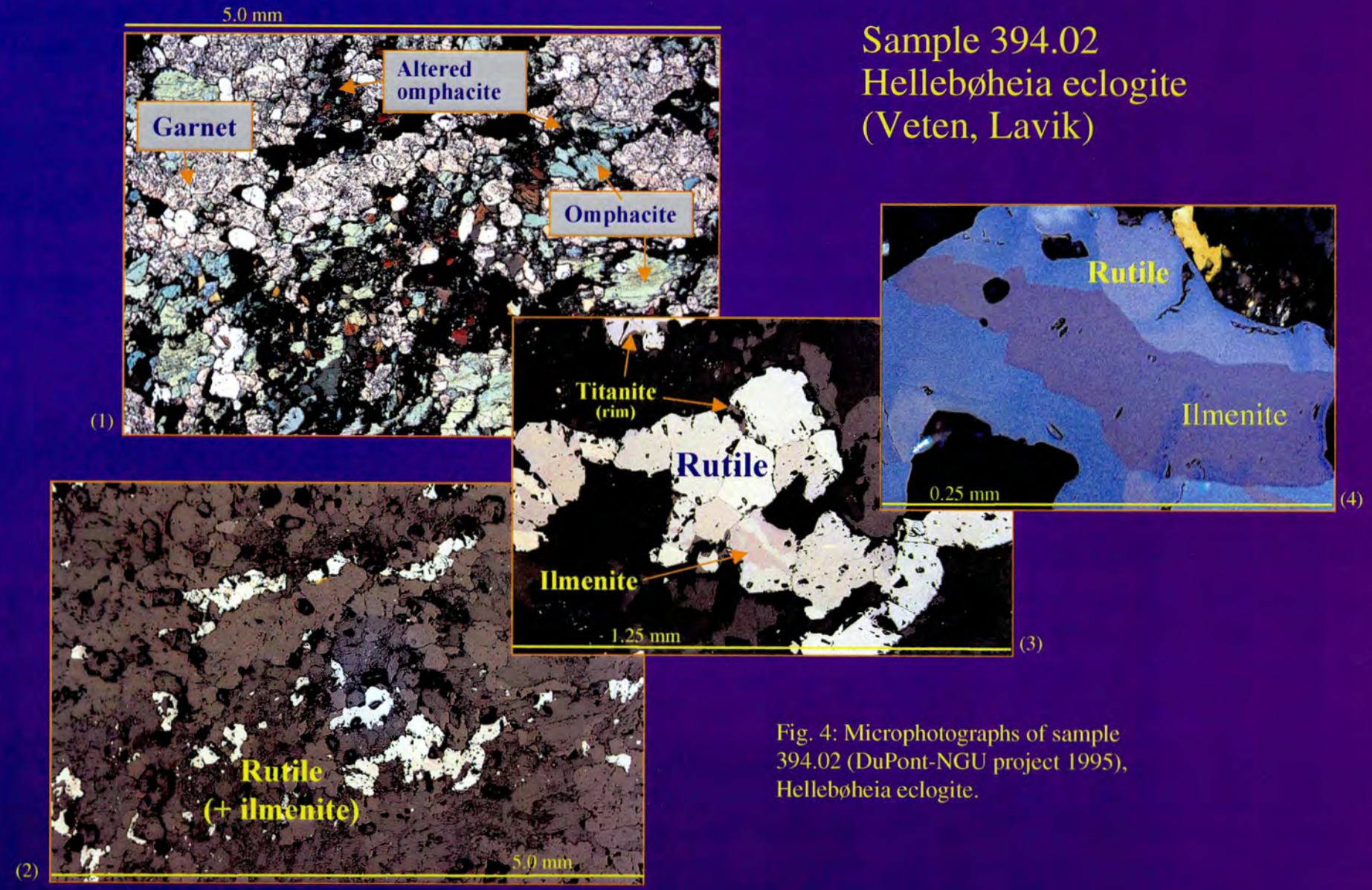


Fig. 4: Microphotographs of sample 394.02 (DuPont-NGU project 1995), Hellebøheia eclogite.

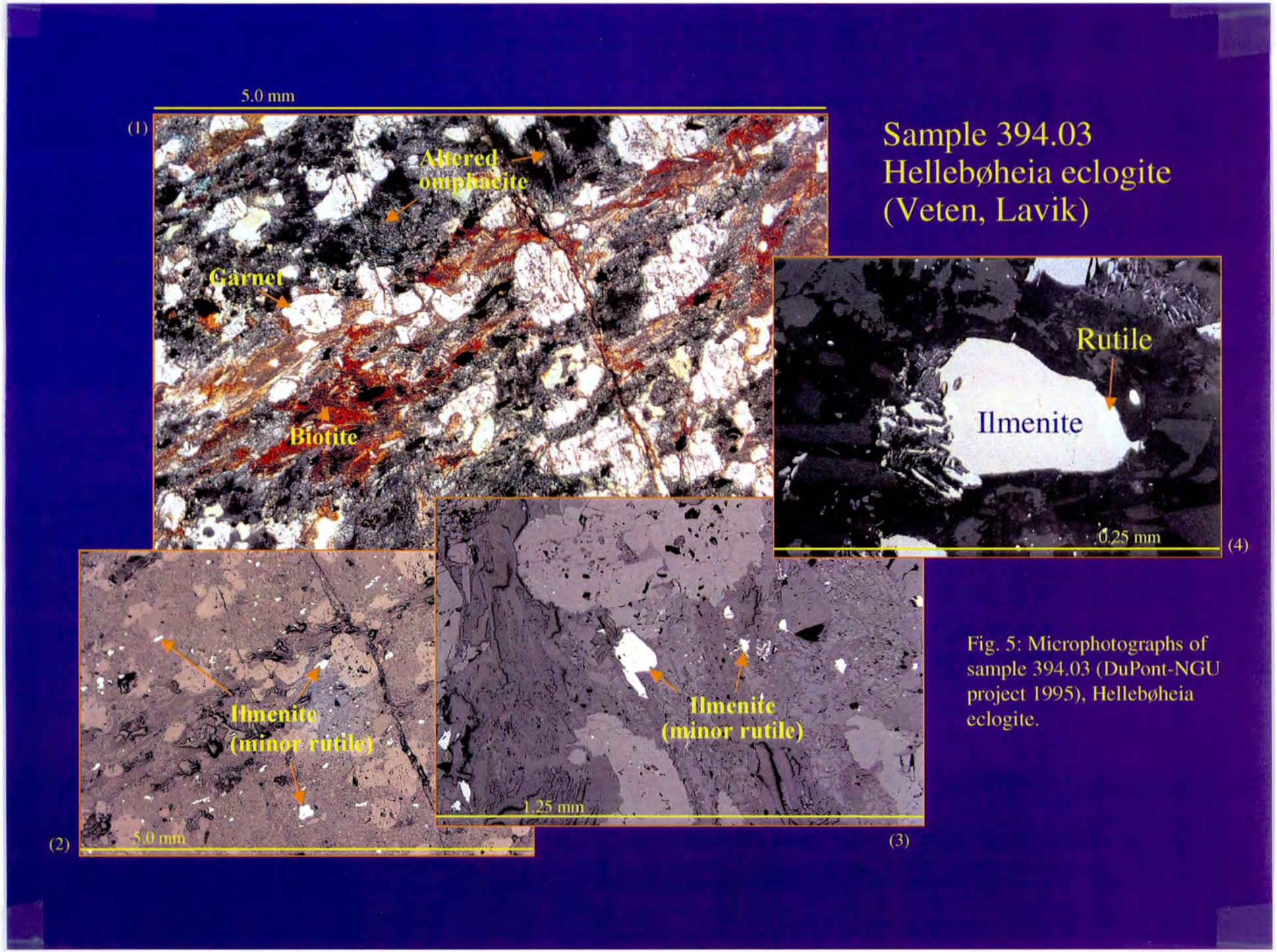


Fig. 5: Microphotographs of sample 394.03 (DuPont-NGU project 1995), Hellebøheia eclogite.

3. ECLOGITES ON THE SOUTHERN SIDE OF SOGNEFJORD

Relatively large amounts of mafic rock occur east and southeast of Brekke, on the eastern side of Risnefjorden. In some places these rocks are garnet-bearing, but no relics of eclogite have been found (Korneliussen 1989).

Mafic rocks west of Brekke are eclogitised in small shear zones. Fig 6 (1) shows a gabbroic boudin surrounded by a banded gneiss with eclogitic mafic layers. The eclogite is believed to have been formed by the deformation of the gabbro, i.e. eclogitisation was triggered by the deformation. Fig. 6 (2) is a close-up photo of this gneiss, while Fig.6 (3) shows a thin eclogite zone formed along a small shear zone in gabbro. In these cases eclogitisation has been incomplete. This phenomena is well described from the Holsnøy area near Bergen by Austrheim and others (see references in Korneliussen et al.1999). However, the corresponding eclogite deposit sizes are very small.

No indications of significant eclogites have been observed in the Brekke-Risnefjorden area, and continued investigations are not recommended.

4. ECLOGITES ON ISLANDS IN THE GULEN AREA

Numerous small amphibolitic to eclogitic lenses occur within the granitoid gneisses between Dalsfjell in the east and Byrknesøy in the west. The occurrence of these rocks is well delineated on the Byrknesøy geological map (Fig. 7). Characteristically the mafic rocks are amphibolitic (garnet amphibolites), occasionally with distinct relicts of omphacite as symplectitic plagioclase-amhibole.

The Veten eclogite (Fig. 7, 8, 9 and 10) is the only significant deposit in the area. It is an East-West trending lens, approximately 1 km long and 300-400 meters at its widest point, disappearing above the erosion plane in the east, and probably continuing at depth in its western continuation. It is significantly retrograded (amphibolitised) and some of the rutile is altered to ilmenite and occasionally also to titanite.

TiO_2 contents are in the range 2-3 wt.%, locally up to approximately 4 wt.% TiO_2 based on field X-Met analyses done in 1995 by the NGU-DuPont project. This information was not reported since that project shortly afterwards focused 100% on the Engebøfjellet deposit at Førdefjord.

Microphotographs of 2 thin-sections are shown in Figures 9 and 10. Both are of distinctly retrograded eclogite with significant alteration of omphacite to fine-grained aggregates of plagioclase and amphibole. The rutile is partly altered to ilmenite, now seen as rutile/ilmenite intergrowths.

All in all, the rutile portion of the total titanium in the rock is estimated to 60-80 %, and the average rutile content is roughly estimated to 2 %.

The Veten eclogite is the largest eclogite known in the Sognefjord-Gulen region. With an estimated average thickness of 100 m, a length of 1000 m, an average width of 300 m and a density of 3.2 t/m^3; its tonnage is roughly 100 million tons.

It is unlikely that the Veten eclogite is sufficiently rutile-rich enough to be of economic interest. However, further investigations should be carried out to define roughly the beneficiation characteristics before any decision is taken concerning additional field investigations.

Eclogitisation in shear zones

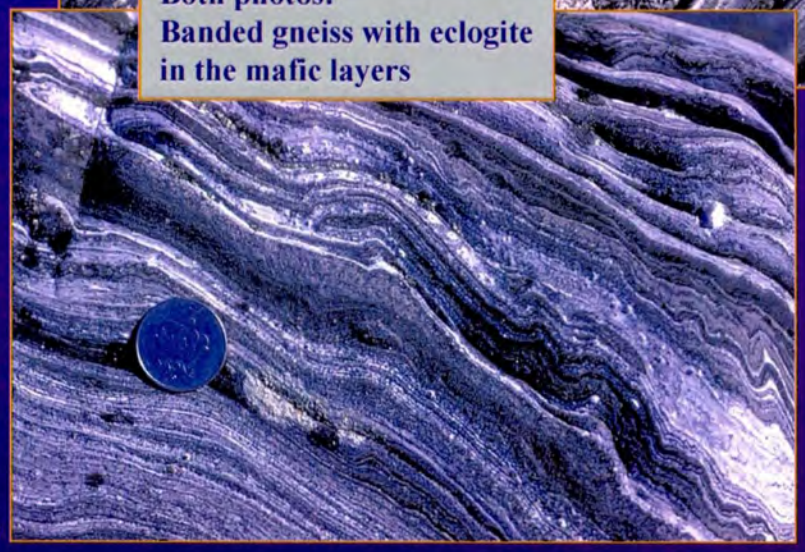


Fig. 6: Examples of shear zone induced eclogitisation at the south side of Sognefjord. (1) Relict gabbro lens surrounded by banded gneiss in which the mafic layers are eclogitic. (2) Close-up photo of the banded gneiss with eclogitic mafic layers. (3) Eclogitised gabbro along a shear zone.

Geological map of Byrknesøy
(after Inger Winsvold 1996)

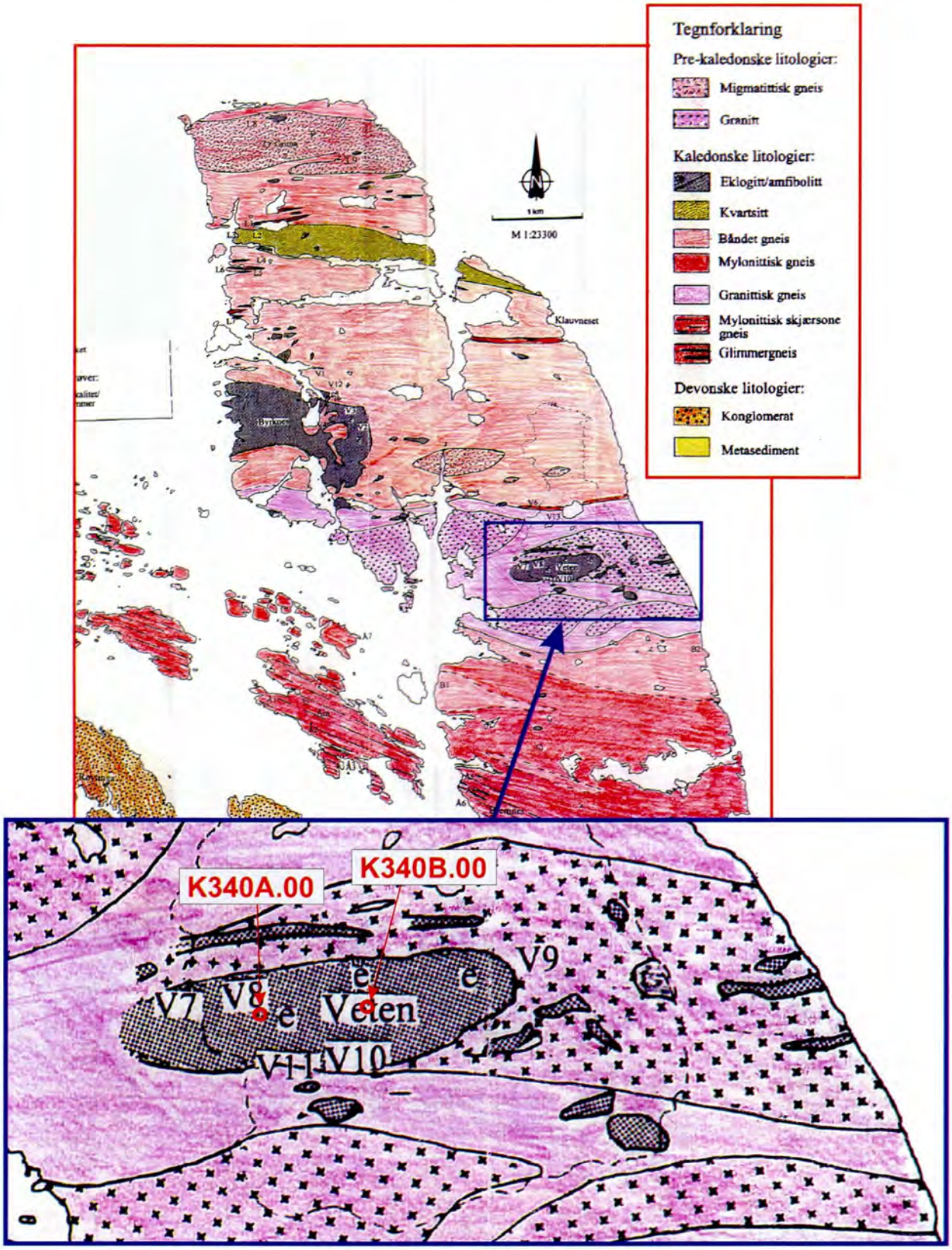


Fig 7: Geological map of Byrknesøy including the Veten eclogite (after Winsvold 1996). The sample localities K340A.00 and K340B.00 are indicated.

Veten

Rutile-bearing eclogite, Byrknesøy, Gulen, W. Norway

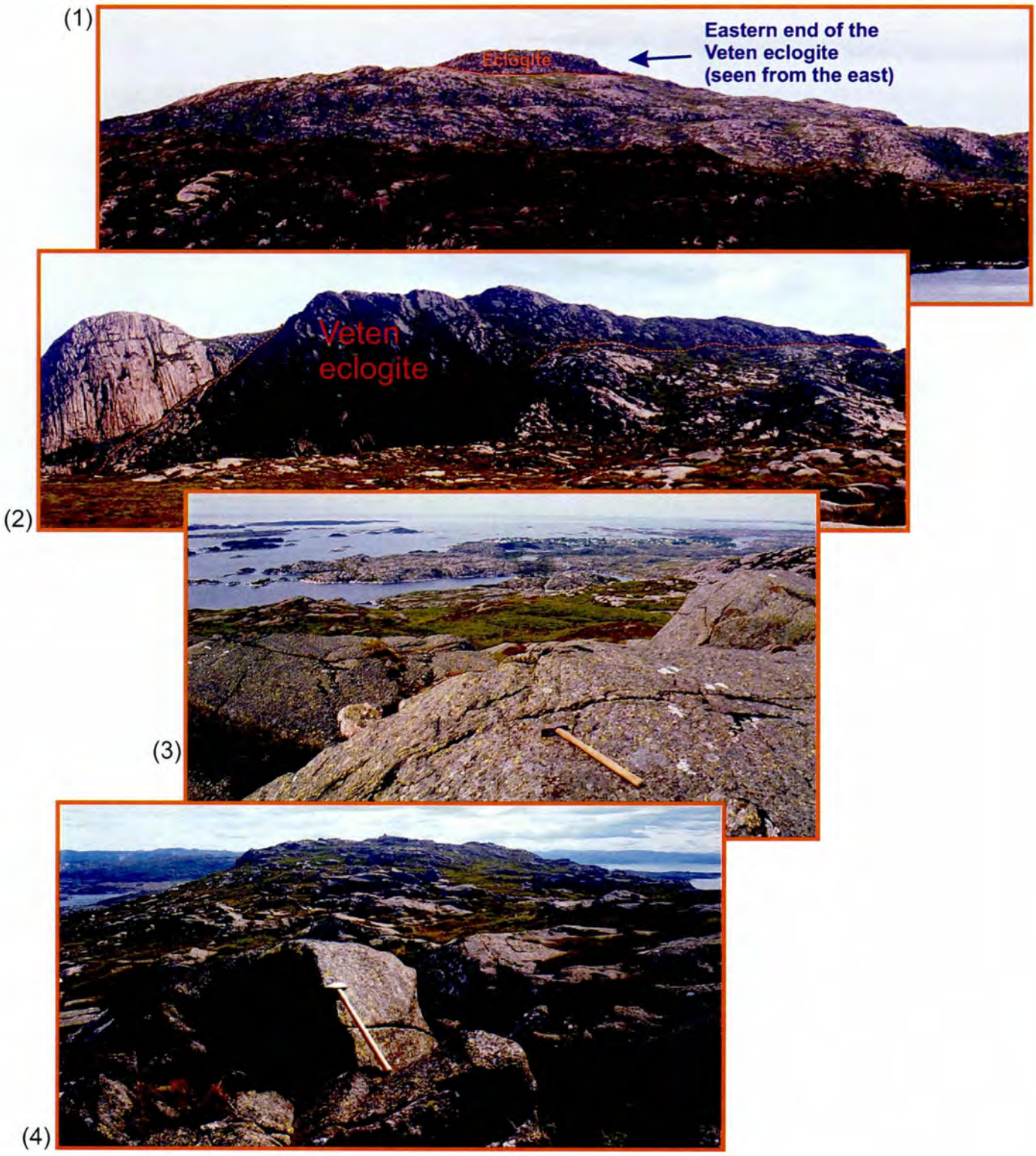


Fig 8: Photographs, Veten eclogite, Byrknesøy. (1):The veten eclogite seen from the east. (2): The Veten eclogite seen from the south-west. (3) View from the top of Veten westwards. (4) View from the top of Veten eastwards.

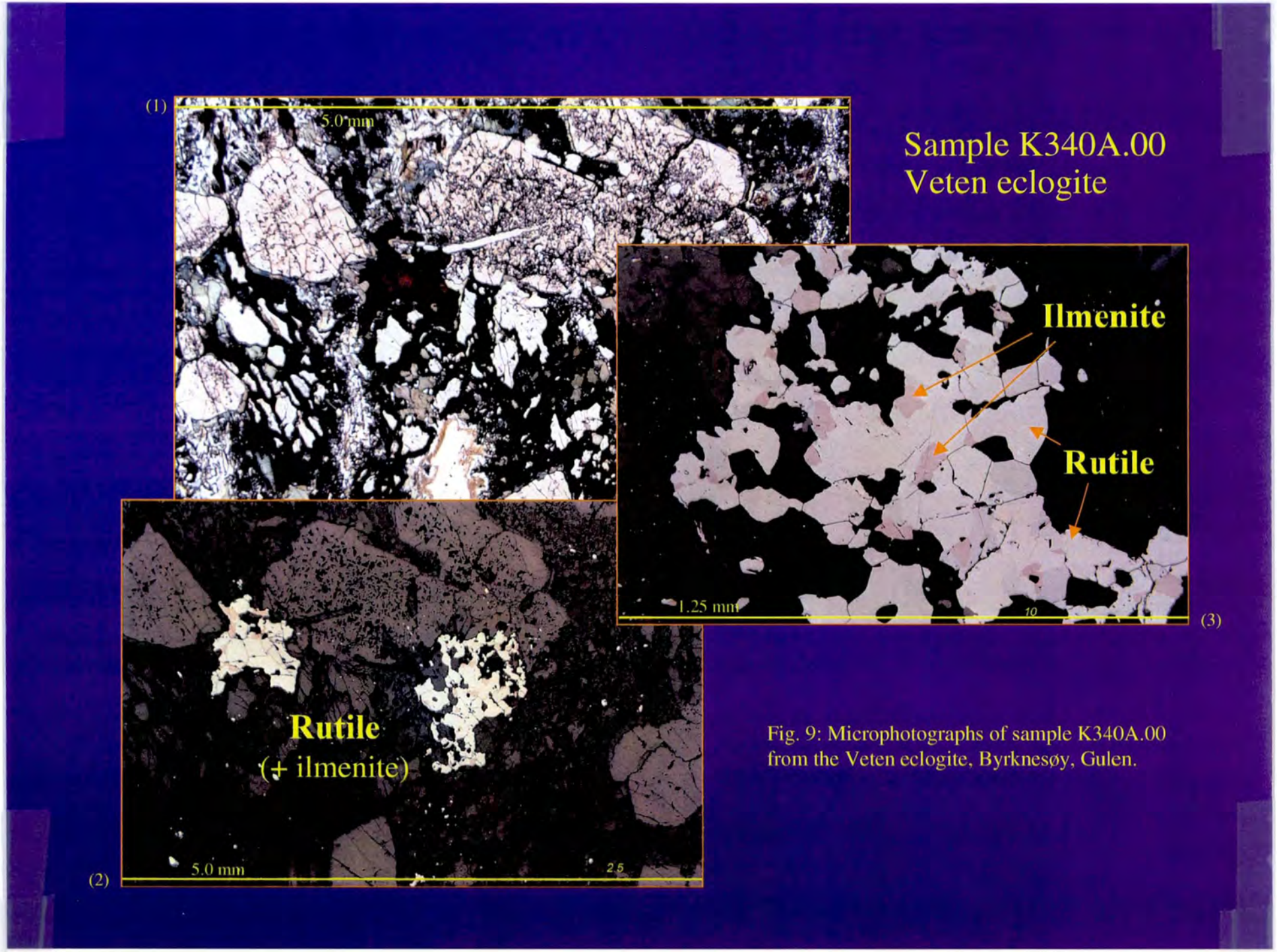


Fig. 9: Microphotographs of sample K340A.00 from the Veten eclogite, Byrknesøy, Gulen.

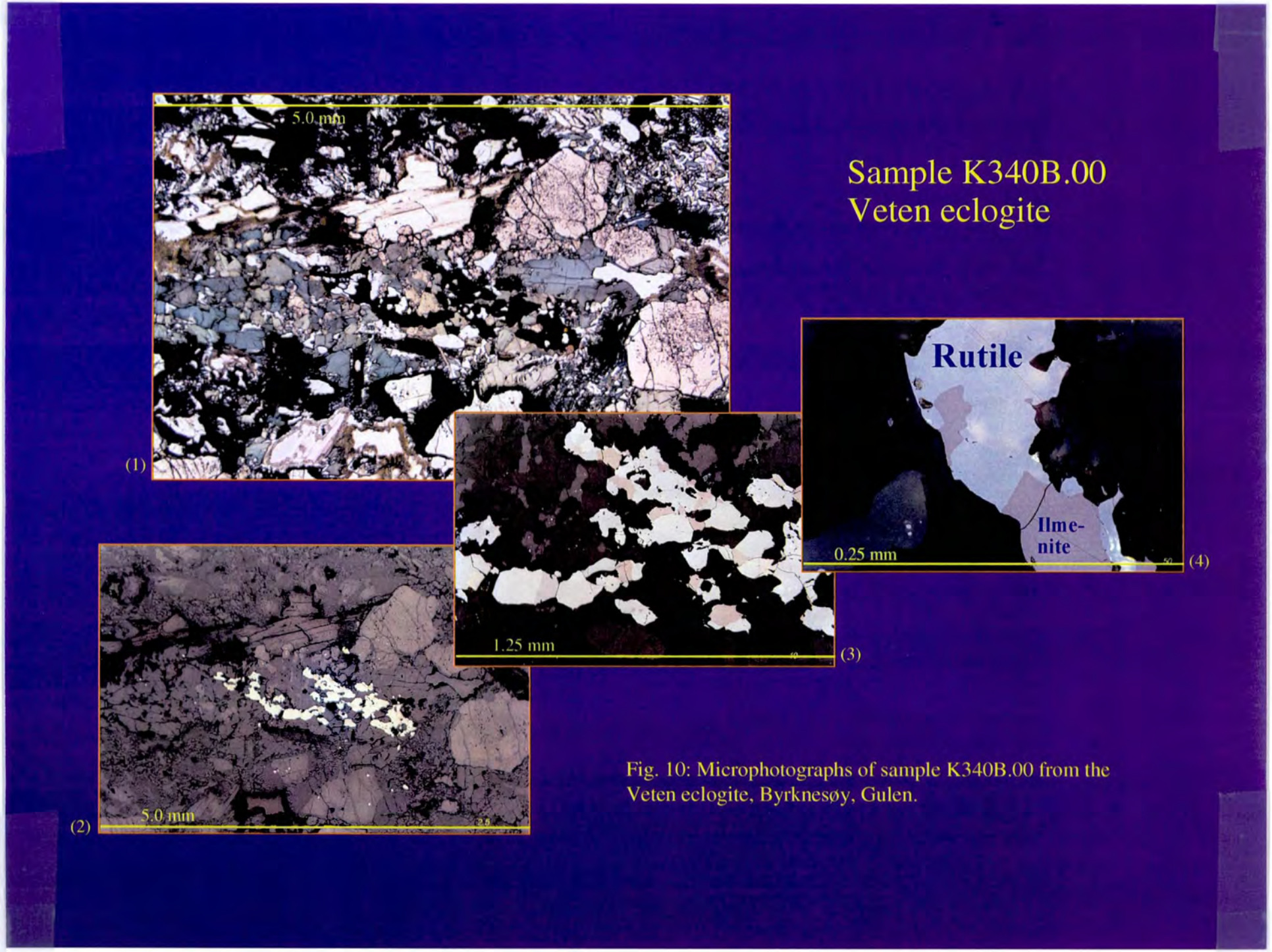


Fig. 10: Microphotographs of sample K340B.00 from the Veten eclogite, Byrknesøy, Gulen.

5. ECLOGITES IN THE DALSFJELL AREA

The Dalsfjell area (Fig. 11) was the subject of a preliminary investigation by NGU in 1988 (Korneliussen 1989) and was regarded to be of minor interest for rutile, due to relatively low grades, incomplete eclogitisation and small deposit size, at least when compared with eclogites in the Førdefjord area. The Dalsfjell area is characterised by a relatively large gabbroic massif (see the map labelled (3) in Fig. 2 and Fig. 11) with an overall content of 1-3 % TiO_2, locally reaching 3-4 %. The dominant titanium-bearing mineral is ilmenite. Dm-thick semi-massive to massive apatite-rich magmatic (cumulate) layers of Fe-Ti oxides (titanomagnetite and ilmenite) are found a few places in the Slengesol area.

In general, eclogitisation is incomplete, and distinctly associated with shear zones. Relatively continuous areas of eclogite over a few hundred meters are found only at Slengesol, Norddal and Kjelbju (Fig. 2) with roughly 3 % TiO_2 in average, of which 50-80 % is as rutile. The rutile in the Dalsfjell eclogites is particularly fine-grained and probably even more fine-grained than the eclogites at Førdefjord.

Microphotographs of 3 thin sections of samples from Slengesol are shown in Fig. 12, 13 and 14. Fig. 12 is of a metagabbro which has not reached the stage of eclogite. The stable Ti-oxide in this rock is ilmenite with hematite exsolutions, rimmed by titanite. Fig. 13 is of another metagabbro with magnetite, ilmenite and hematite. Fig. 14 is of eclogite that has experienced significant retrograde alteration in which omphacite is altered to fine-grained aggregates of plagioclase and amphibole (the dark areas in photo (1)), and rutile is partly altered to ilmenite, now present as rutile/ilmenite intergrowths (Fig. 14 (3)). The sample from Kjelbju is less retrograded, although a distinct portion of the titanium occurs as ilmenite.

Further investigations are not recommended due to the combination of relatively low TiO_2-content, relatively small deposits due to incomplete eclogitisation of the gabbro, and retrograde alteration of eclogite. Due to these circumstances the rutile content would probably be too low (2 % rutile or so) to justify any further investigations.

6. CONCLUSIONS

The following three circumstances are relatively unfavourable regarding the possibilities for economic rutile deposits: (1) Incomplete eclogitisation of gabbroic rocks, primarily in the eastern and south-eastern parts of the region, causing the overall portion of titanium as rutile in these variably retrograded rocks to be low. (2) In the western parts of the region eclogites tend to be severe amphibolitised, leading to distinct alteration of rutile to ilmenite and occasionally also to titanite. (3) The overall titanium grade in the larger eclogite bodies tend to be in the range 2-3 %, which is probably too low when considering that a distinct, but variable portion of the titanium is as ilmenite.

With the exception of the Hellebøheia eclogite on the northern side of Sognefjord, for which a gravity investigation should be considered, no further investigations are recommended for the Outer Sognefjord – Gulen region.

Table 2: XRF-analyses of metagabbroic and eclogitic rocks from the Dalsfjell area (after Korneliussen 1989).

Sample	% Fe_2O_3	% TiO_2	% P_2O_5	Comments	Sample	% Fe_2O_3	% TiO_2	% P_2O_5	Comments
4A	15.12	3.50	3.11	Metagabbro	D1	16.53	2.59	0.45	Eclogite
D10	12.32	2.48	2.22	Garnetamphibolite	D11	14.63	3.00	2.64	Eclogite
D14	18.60	3.77	3.64	Metagabbro	D13	12.96	2.68	2.31	Eclogite
D15	14.20	2.73	1.30	Amphibolite	D16	14.88	3.25	2.59	Eclogite
D17	22.73	3.83	6.19	Metagabbro	D24	16.23	3.40	2.81	Eclogite
D18	14.65	2.98	2.35	Garnetamphibolite/Eclogite	D25	16.09	3.26	2.26	Eclogite
D19	17.11	3.36	2.44	Garnetamphibolite/Eclogite	D26	13.57	2.80	2.25	Eclogite
D2	10.14	2.09	1.52	Amphibolite	D28	17.37	2.82	0.55	Eclogite
D20	18.78	3.35	2.76	Garnetamphibolite/Eclogite	D29	17.23	2.69	0.53	Eclogite
D21	9.92	2.16	1.75	Metagabbro	D30A	17.75	2.94	0.62	Eclogite
D22	23.09	4.90	2.47	Garnetamphibolite/Eclogite	D32	14.43	3.61	0.36	Eclogite
D30B	10.35	2.41	1.72	Metagabbro	D3B	16.97	3.18	3.26	Eclogite
D31	9.04	2.18	1.67	Metagabbro	D43A	18.77	3.62	1.05	Eclogite
D33	3.70	0.60	0.14	Metagabbro	D43B	24.73	4.75	0.41	Eclogite
D34A	11.49	2.40	2.23	Metagabbro	D46	12.66	2.66	1.94	Eclogite
D34B	17.29	2.65	2.38	Metagabbro	D47	17.47	3.16	3.03	Eclogite
D35	14.58	2.85	1.58	Amphibolite	D48	16.76	2.79	0.54	Eclogite
D36	12.81	2.05	0.90	Amphibolite	D49	16.90	2.76	0.62	Eclogite
D37	1.18	0.18	0.05	Granitic Gneiss	D5	16.38	2.89	2.11	Eclogite
D38A	11.70	2.41	1.50	Metagabbro					
D38B	13.43	2.12	1.14	Garnetamphibolite					
D39	15.18	3.03	1.57	Metagabbro					
D3A	13.22	3.30	1.30	Metagabbro					
D40	15.61	3.24	1.43	Metagabbro					
D42	23.29	4.47	0.35	Amphibolite					
D44A	13.18	2.72	3.02	Metagabbro					
D44B	27.70	4.58	6.44	Metagabbro					
D44C	14.03	2.59	3.41	Metagabbro					
D45	31.06	6.09	2.66	Metagabbro					
D4B	18.20	4.29	3.71	Garnet amphibolite					
D8	11.43	2.57	1.95	Metagabbro/Amphibolite					
D9	12.21	2.53	2.08	Garnetamphibolite					

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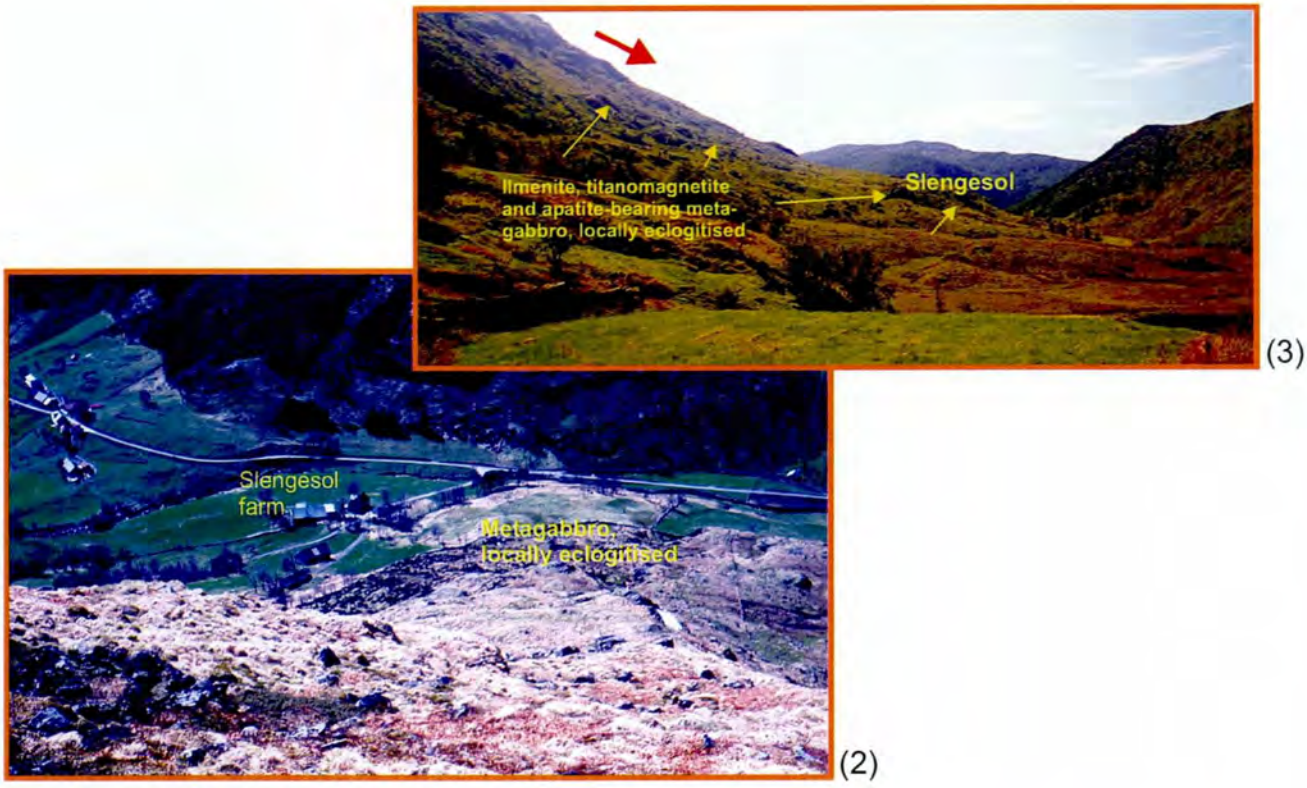

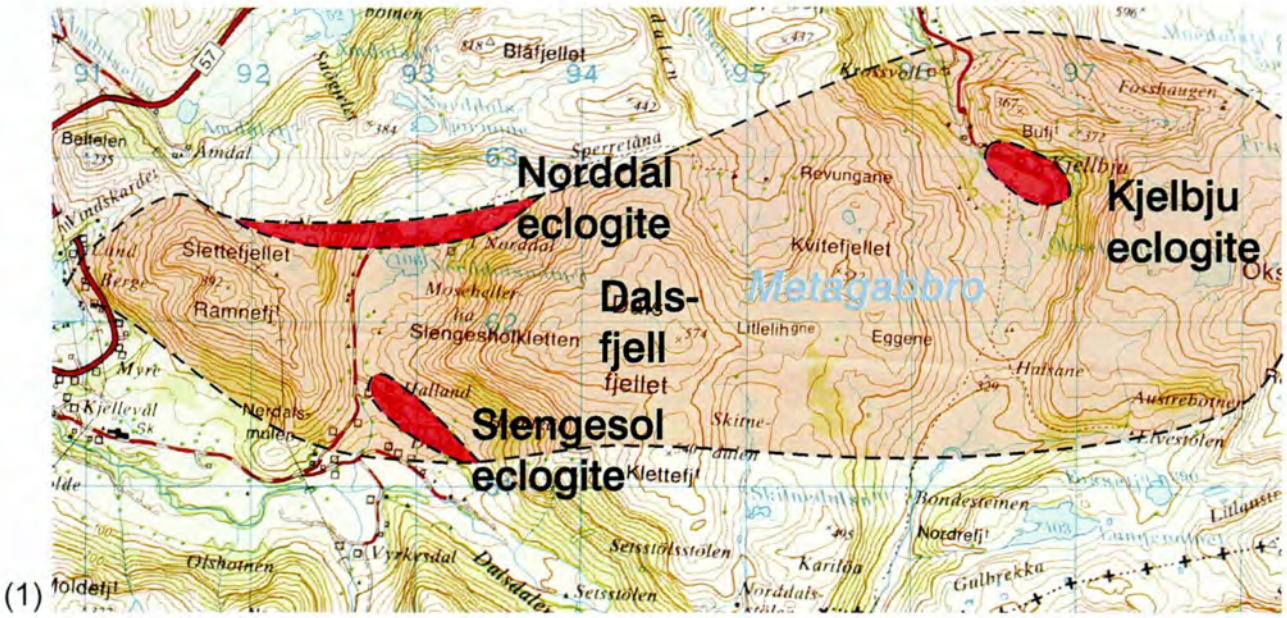

Fig. 11: Map of the Dalsfjell area (1) with the eclogite deposits Slengesol, Norddal and Kjelbju. These eclogites are not continuous, but contains parts of incompletely eclogitised metagabbro. Due to significant soil and vegetation overburden the relative proportion of eclogite vs. meta-gabbro is unknown. Photo (2): Slengesol seen from above roughly as indicated by the red arrow on photo (3). Photo (3): View from Norddal towards Slengesol.

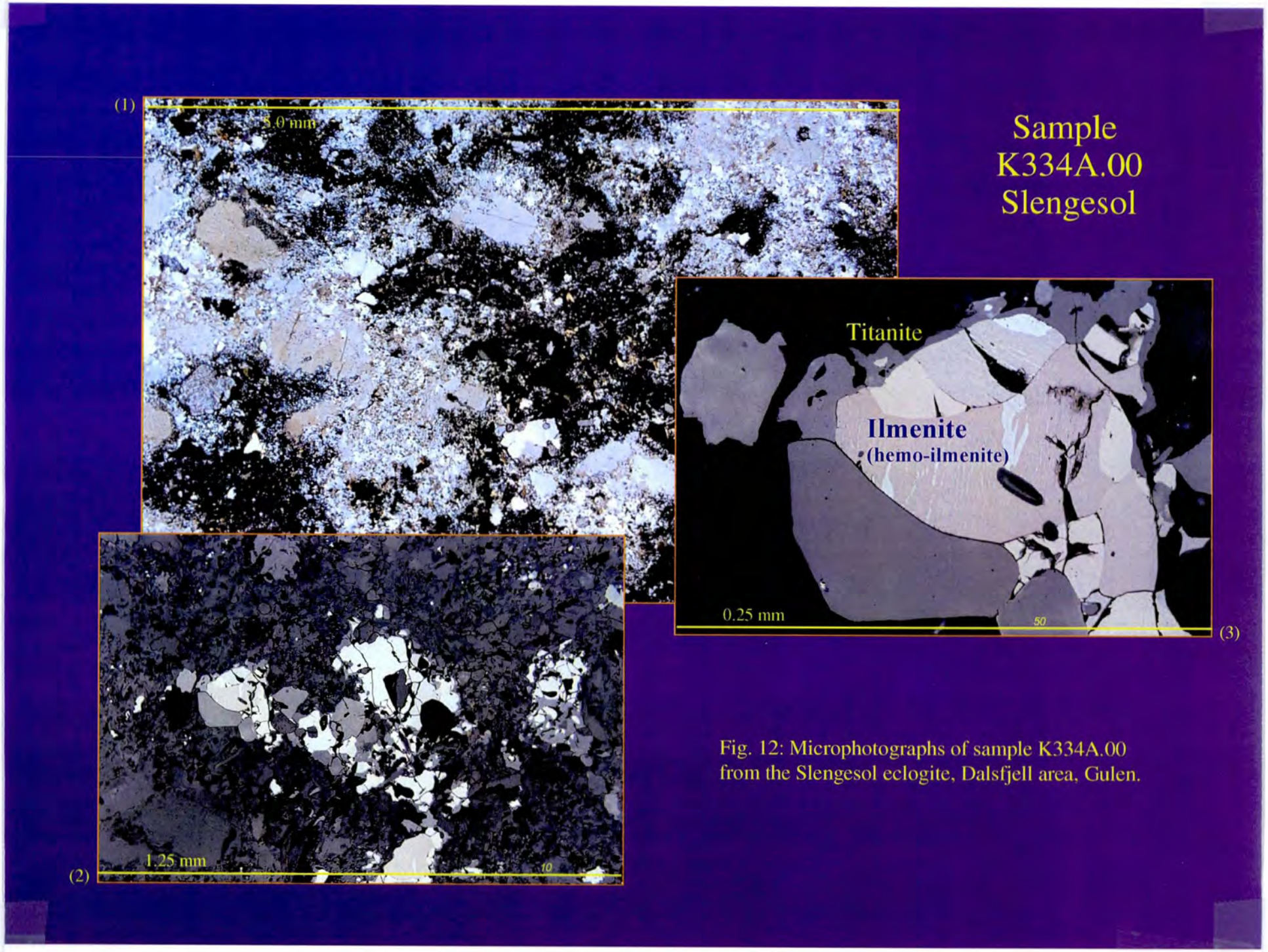

Fig. 12: Microphotographs of sample K334A.00 from the Slengesol eclogite, Dalsfjell area, Gulen.

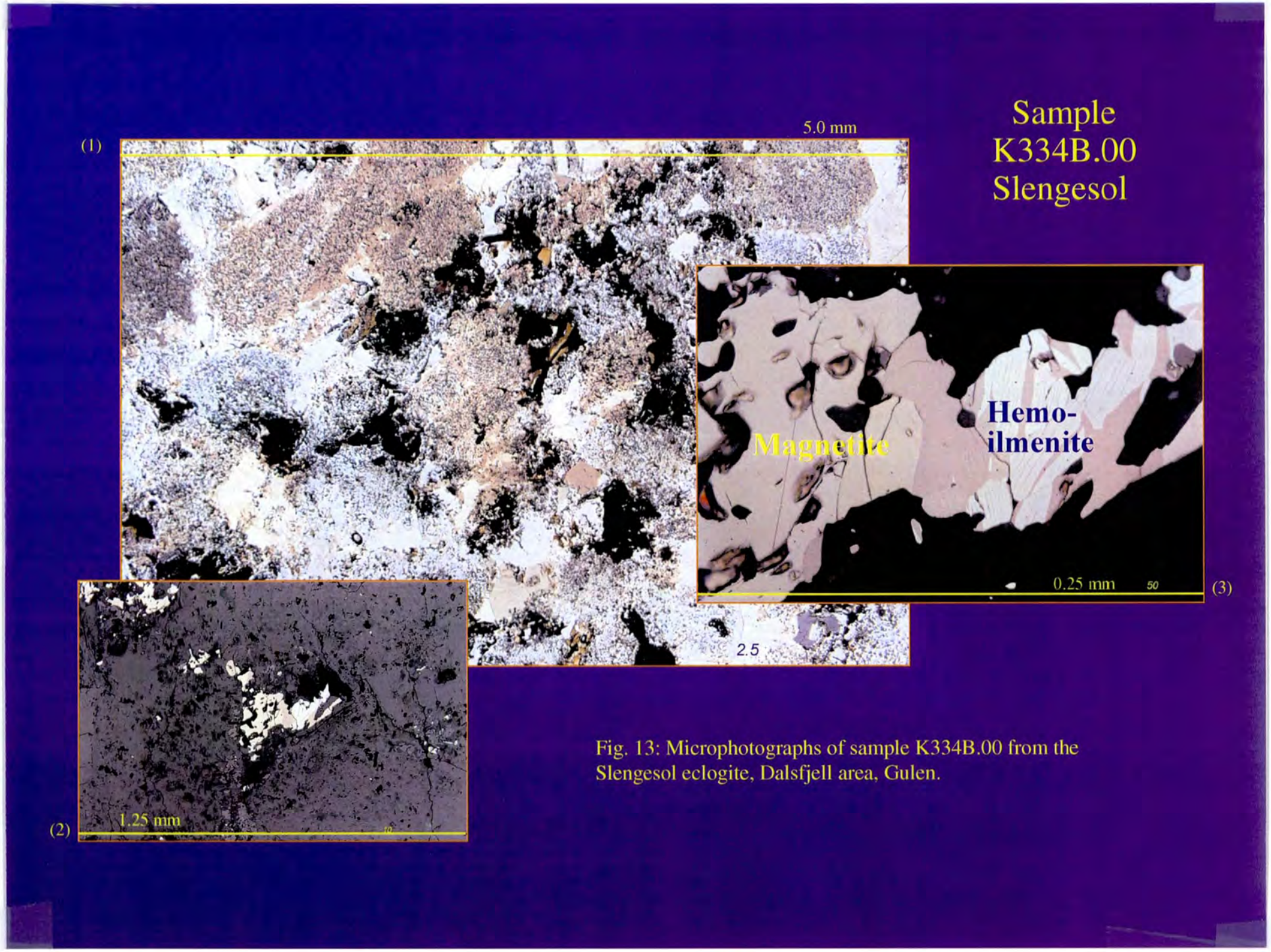

Fig. 13: Microphotographs of sample K334B.00 from the Slengesol eclogite, Dalsfjell area, Gulen.

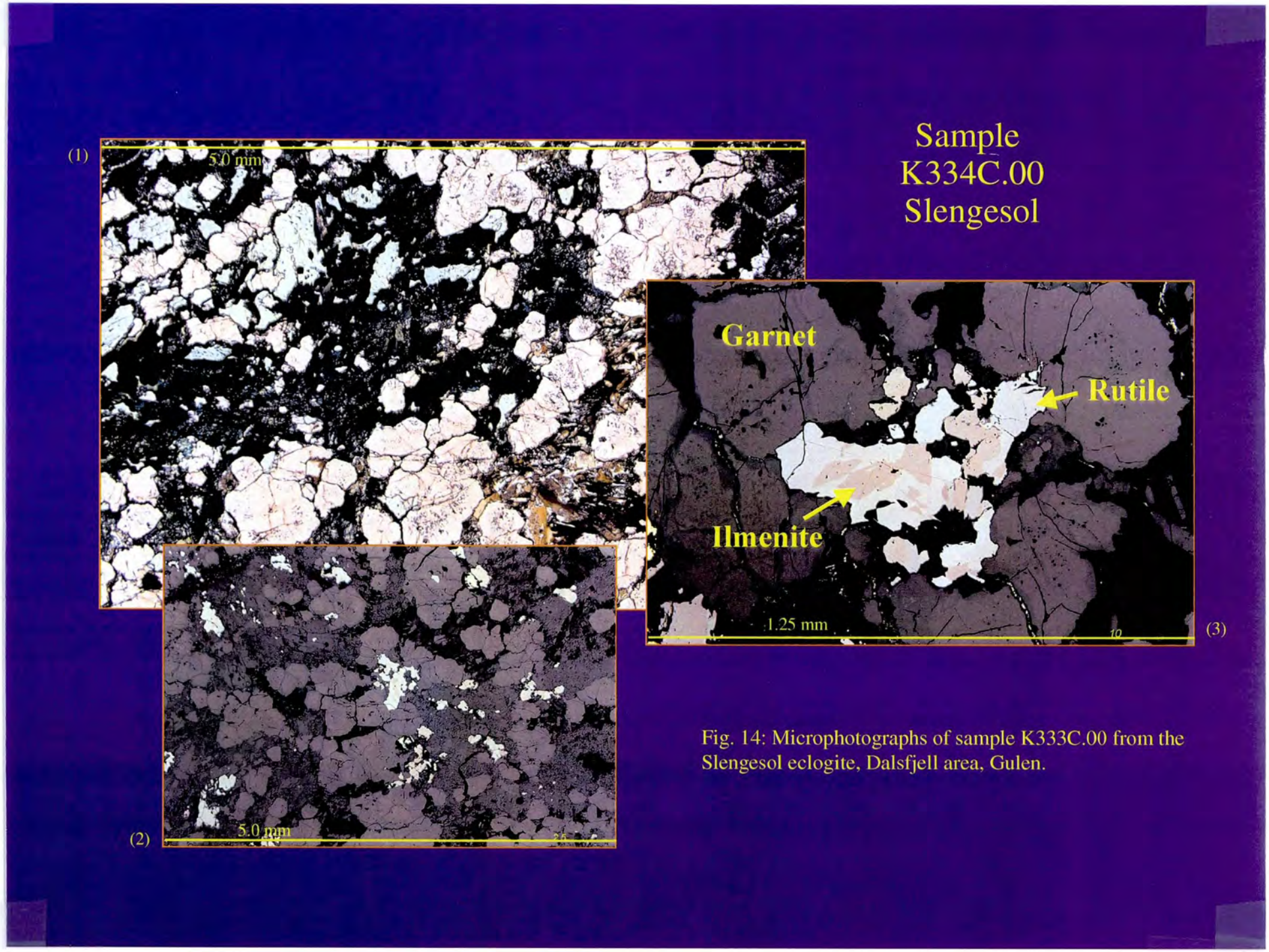

Fig. 14: Microphotographs of sample K333C.00 from the Slengesol eclogite, Dalsfjell area, Gulen.

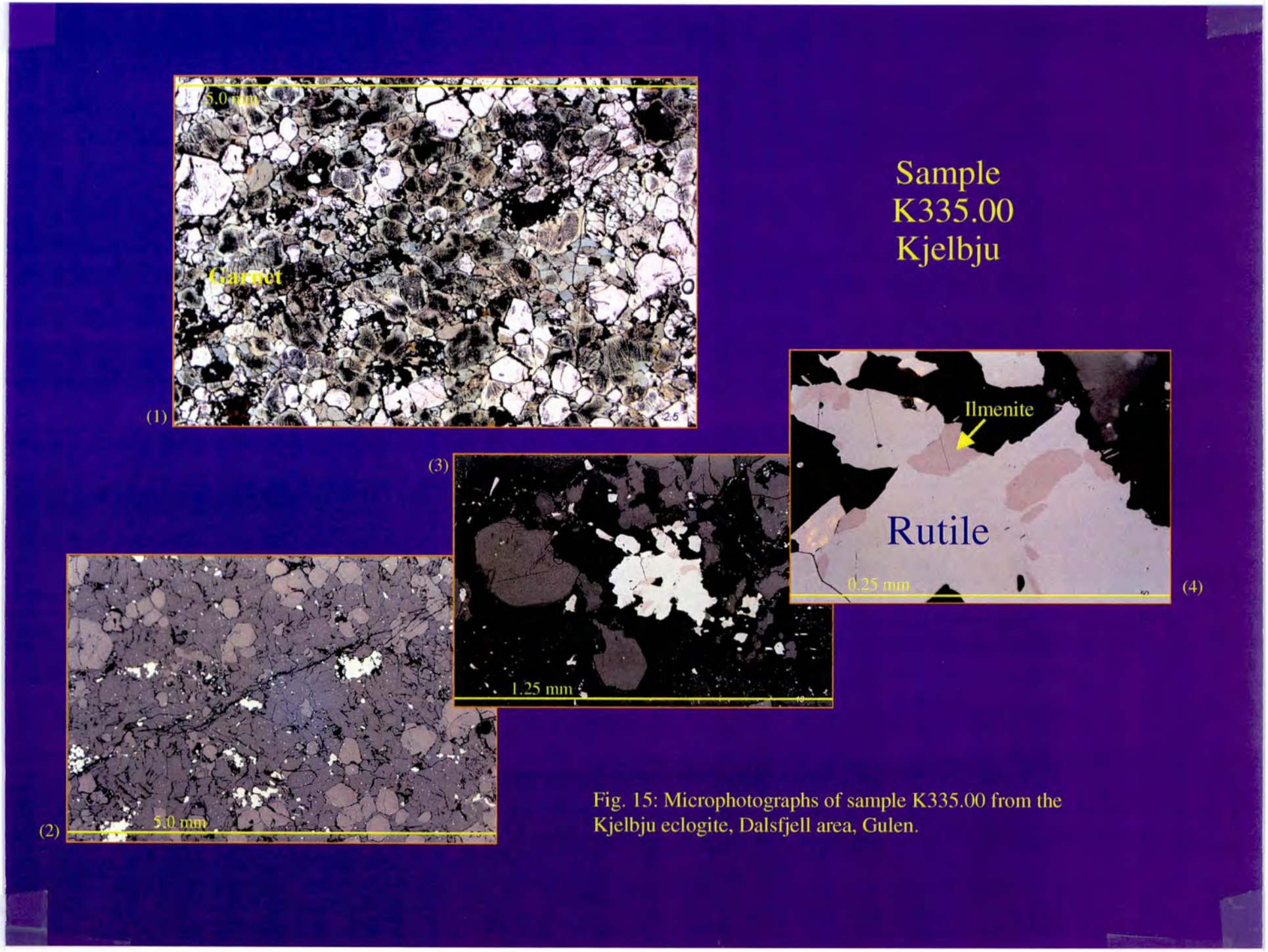

Fig. 15: Microphotographs of sample K335.00 from the Kjelbju eclogite, Dalsfjell area, Gulen.